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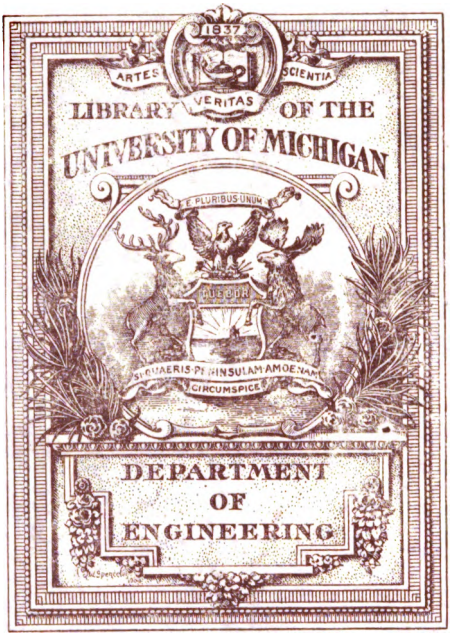
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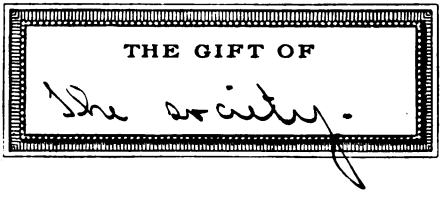
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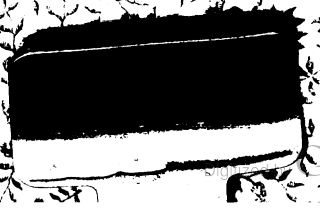

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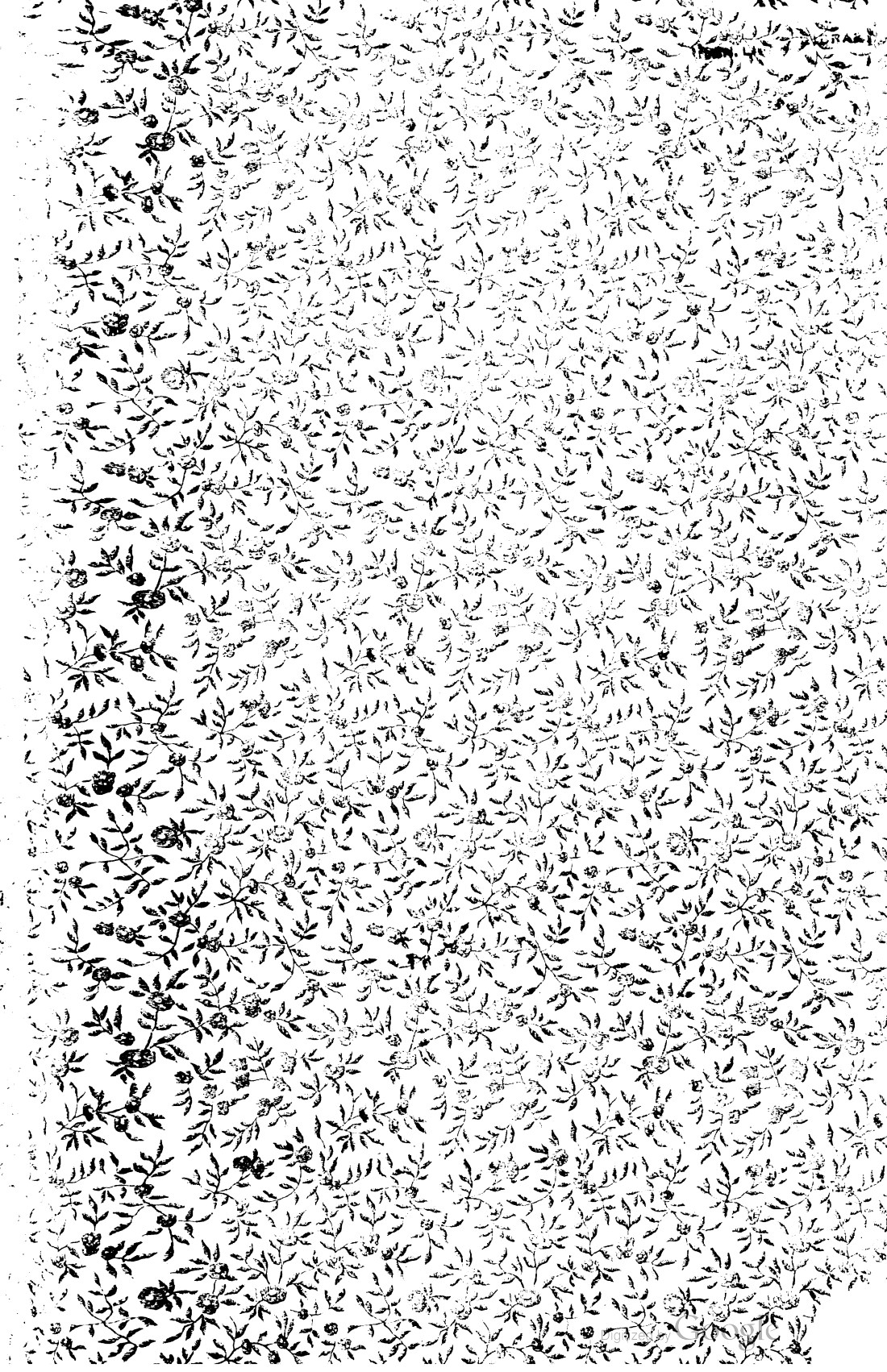

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TRANSACTIONS

OF

# THE AMERICAN SOCIETY

OF

# HEATING AND VENTILATING ENGINEERS

VOL. XIII.

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THIRTEENTH ANNUAL MEETING
NEW YORK, JANUARY 22-24, 1907

SUMMER MEETING
MILWAUKEE, WIS., JULY 18-19, 1907

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# CLXIX.

# THE AMERICAN SOCIETY

OF

# HEATING AND VENTILATING ENGINEERS.

THIRTEENTH ANNUAL MEETING.

Held in the New Engineering Building, 29 W. Thirty-ninth Street, New York City, January 22, 23 and 24, 1907.

## PROCEEDINGS.

### First Day—Afternoon Session.

Tuesday, January 22, 1907.

The meeting was called to order by President Gormly at 2.30 P. M.

Secretary Mackay: Before calling the roll I would announce that the following persons have been elected to membership in the Society since the last meeting:

| | |
|---|---|
| John R. Allen | Member. |
| Albert Aschaffenburg | " |
| Arthur H. Barker | " |
| Frank H. Chisholm | " |
| George H. Crawford | " |
| Edward D. Densmore | " |
| J. Prator Dugger | " |
| George M. Getschow | " |
| Edward B. Gordon, Jr. | " |
| William C. Green | " |
| Fred. K. Houston | " |
| Frank N. Jewett | " |
| George H. Kirk | " |

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John H. Kitchen.....Member.
Foster W. Lamb..... "
Edwin A. May..... "
Charles D. McArthur..... "
Chas. F. Newport..... "
Edward J. Ryan..... "
John J. Spear..... "
Thomas Tait..... "
Alvin W. Varney..... "
Theo. Weinshank..... "
Harvey R. Willard..... "
William C. Wolf..... "
James H. Martin, Jr.....Associate.
Lloyd G. McCrum..... "
Mark E. Monash..... "
William M. Scudder..... "
Norman A. Hill.....Junior.
Harry J. Ott..... "
Alf. Tjersland..... "

Secretary Mackay called the roll and reported a quorum present.

President Gormly then read his address, as follows:

PRESIDENT'S ADDRESS.

Gentlemen: In the name of The American Society of Heating and Ventilating Engineers, I extend to you all a most hearty welcome to this, our thirteenth annual meeting. I trust you will take part freely in our deliberations, because an interchange of opinions and experience is beneficial to all. Aristotle says, "Were it not for an interchange of good fellowship and acts of mutual kindness, society could not exist." This truth applies as well to our Society as to society in general. Let us endeavor to mutually benefit each other during our deliberations, bearing in mind the admonition of Epictetus, that, but a limited time is given to each of us to do all the good he can do in this world and we should do it while we have the opportunity. As he puts it: "There is a boundless abyss of the past, there is a boundless abyss of the future; our period is but a point of time as compared with the

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countless past and the immeasurable future." This being indisputable, we would fail in our duty to ourselves as well as in our duty to our fellow men were we to neglect this opportunity that appears for our mutual advantage. To many of us such an opportunity may never return.

In this age of practical utility, we devote our energies to commercialism, forgetting that man is a composite being, with attributes far transcending his animal nature. We neglect almost entirely the fascinations of scientific research, which when properly appreciated thrill the souls of cultured men to such an extent that they neglect to feed and clothe themselves. We read in Herodotus that when the king of the Scythians sent a delegate to Greece to bring to the Scythians the science of the Greeks, the delegate reported that all the Grecian people were occupied in scientific investigations excepting the Lacedemonians. The ancients were scientists. But we hold our faces to the commercial grindstone without a thought of the higher and more fascinating things just hidden from our gaze, as the vein of precious ore is hidden from the miner.

We are quick to adapt to our material advancement the scientific knowledge transmitted to us by others; but we do not originate scientific investigation to the extent that we should. We have thought out more efficient means of applying to commercial use the facts which true scientists have handed down to us: but where would our advancement be to-day were our ancestors as unscientific and commercial in their time as we are in ours? The pleasures of true scientific research are totally unknown to many of us. We take the shining piece of gold which close application to drudgery justifies us in accepting; but we do not know, nor do we care how it is produced in nature, nor by what chemical formula it is extracted from the rock in which nature placed it. In the matter-of-fact way we are like the ox, which enjoys the corn but cares not how it is germinated, cultivated or harvested.

If we hold our faces, in the future, to the commercial grindstone as we have done in the past, we will never attain that scientific perfection in heating and ventilation which will abolish the hot-air furnace, the steam and water heaters, the radiators, the ashes, the smoke, and the wasted energy of our present cumbrous and expensive systems. The art of heating is in its infancy. It

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will stay there forever, unless we tear ourselves from the rut into which we have fallen.

Astronomers tell us that the sun, as seen through whirlpools of its own vapor, is not heated even to redness. That it is a dark body. Could we but discover the generating formula of the sun's heat, we would be far on the road to successful scientific heating. The time cannot be far distant when the forces of nature will be so understood and utilized that heat rays will be as dirigible as electric forces now are in the transmission of wireless telegrams. We utterly fail in our duty when we devote our energies to the commercial feature of heat transmission to the entire neglect of scientific investigation. One hour each day devoted sacredly to scientific investigation by each member of our Society would hardly bankrupt us and would make us rich intellectually.

The Electric Engineer and the Chemist are forging ahead and will overlap our field of duty if we neglect it.

The forces of nature which we could utilize almost overwhelm us. At the present moment 30 square miles of lava heated white are flowing from one volcano in the Sandwich Islands. Can we estimate the heat-units wasted in that flow? They are almost incalculable. The outlines of continents are changed by volcanic action. The active power of volcanoes is uncontrolled heat. Each summer storm fills our atmosphere with sheets and bolts of fire, yet we look on, as a horse or an ox might do, without an effort to harness these forces. We are for months so oppressed with excessive summer heat, that we flee to the mountains for relief, yet we make no motion to utilize this excessive summer heat that we may mitigate the rigors of the winter which is sure to follow. If the excess of heat were stored as electricity is stored, we might laugh the wintry blizzards to scorn. Do any of you imagine it is beyond the possibilities to store it and to liberate it as needed? We are as infants in our chosen profession. We will be the joke of future generations, for coming so near perfection in heating without attaining it.

Another matter calls loudly for our very serious attention. If you will read the history of our Society in its incipiency, you will see, in our printed Proceedings, that when we had but seventy-five members, we had an abundance of good papers presented for discussion. You will also note that with four times

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that membership, we now have no more papers than were first presented. What must we infer from this? Either that our present members are four times as indolent, or that they are four times as incompetent, or that they have but one-fourth the interest of the first members. This condition of affairs is so radically wrong that its cause should be discovered and eradicated.

You will also note that the principal papers presented year after year are by the same heroes who contribute freely of their time and talent. These men are worthy of much greater consideration than they have ever received. I would suggest that in all future lists of the names of our members, those who have presented a paper which has been accepted by our Society, shall be printed in small capitals and those who have not so distinguished themselves, shall be printed in small letters. Such a distinction may spur those on who never do anything, those who absorb information; but give nothing. It will then be seen at a glance who are workers and who are not. It can work no injustice, for all members will receive just what they deserve. If they desire to be on the roll of honor, they have but to present one acceptable paper. The most onerous task connected with office in this Society is to secure from members a few papers twice a year to be read. Members should vie with each other to crowd the Society with papers. One would suppose from the answers returned when members are asked to contribute a paper on a subject which they have made a special study, that no member has time to eat more than one hurried meal a day. The facts are, that no member is so pursued by the furies of financial disaster, that the few hours needed in twelve months to prepare a paper would reduce him to bankruptcy. It is not the lack of ability. It is not the need of time. It is absolute indifference, or worse, a desire to secure professional information and to give none in return. It is discreditable from any point of view. With a desire to remedy the evil I thus draw attention to it and suggest a remedy. Is it not plain that if all our members were to act in this selfish manner we could not exist as a society? It is vital to our success that a majority of members be active and efficient. If our members will but chart and tabulate the results they have attained with various systems of heating, noting the failures as freely as they note the successes, with the bravery displayed by the surgical profession in publishing their failures as freely as they

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publish their successes in the surgical journals, our Proceedings would then be of incalculable benefit to their possessors. At present we have but little of such information between the covers. What a showing we could present if each member were to chart from one to five such plants, regardless of the success or failure. Have you the nerve to do it?

Our charter states that we are associated for the promotion of the arts and sciences, and for the interchange of knowledge. Every honest means toward that end should be encouraged. The thought has been advanced that we might establish a form of exchange by which we would give copies of our proceedings to members of kindred engineering societies, and receive from them an equal number of copies of their printed proceedings for distribution among our members who desire to secure them. A very small advance above the cost to print and mail such publications might be charged. This charge should be paid by the member receiving such publication. The amount of money to be invested by any one would be slight. If a small addition to the actual cost were charged, it would be a source of revenue to the Society. When the forms are ready to print, the extra cost of printing and mailing a few hundred additional copies would be but little. It is likely many of our members would gladly pay this cost to secure the proceedings of other kindred societies, and they would have many members who would be pleased to receive ours for a small fee. I congratulate you on the fact that this Society has prospered wonderfully during the past year. This you will learn in detail from the reports of the Treasurer and the Secretary.

Secretary Mackay read the following report:

## SECRETARY'S REPORT.

New York, January 22, 1907.

*The American Society of Heating and Ventilating Engineers:*

Gentlemen: Your Secretary would report an increase in membership during the past year. At our last annual meeting our membership was composed of 1 Honorary member, 217 Members, 17 Associates and 8 Juniors, or a total of 243 members of all grades.

During the year we have added 37 members, 6 Associates and

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5 Juniors; 1 Associate was advanced to full membership, 2 members resigned, 1 Junior failed to qualify, 5 members, 2 Associates, and 1 Junior were dropped from the roll for non-payment of dues, and one member, Mr. Herbert W. Nowell, who was elected to membership, June 25th, 1904, died on March 25th, 1906.

Our present membership is 1 Honorary member, 247 members, 20 Associates and 11 Juniors, or a total of 279 members of all grades, making a net increase of 36 during the past year.

The financial affairs of the Society are in good condition. At the last annual meeting there was a balance in the hands of the Treasurer of $633.94. We have received from all sources during the past year $3710.62, which, with the balance on hand, made a total of $4344.56 available.

The total expenditures amounted to $2549.66, leaving a balance in the hands of the Treasurer of $1794.90. There is a balance owing from members for dues, etc., and from newly elected candidates for membership, for initiation fees and dues amounting to $561.25; this, with the balance on hand, amounts to $2356.15.

The members dropped from the roll during the year owed the Society $240.00.

The 1905 Proceedings, which were delayed for a number of reasons, have been completed and will be forwarded to the members at once.

The 1906 Proceedings are well under way and will be printed as soon as the corrected discussion is returned by the members. The total cost of these two years' Proceedings will be about $1925.00. We have no unpaid bills on hand.

The Secretary's expenses for the year, including stenographer, clerk hire, rent of post office box, certificates, pin badges, expenses in connection with the summer meeting, postage, expressage, etc., amounted to $905.82.

The Society held a summer meeting at Chicago, July 19th and 20th, 1906, which was the largest and most successful meeting it has ever held.

The papers for this meeting were late in being received, there was a delay in having the cuts prepared, the papers were received from the printers Monday afternoon and were immediately mailed to the members—two papers will be read from manuscript. The delay in receiving the papers prevents the possibility of the members obtaining a knowledge of them and consequently

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prevents a full and intelligent discussion of them, thus lessening their value and I would urge on the members the desirability of sending in their papers earlier.

Respectfully submitted,

WM. M. MACKAY,
Secretary.

Secretary Mackay read the following report of the Treasurer:

TREASURER'S REPORT.

| | | |
|---|---|---|
| Balance on hand, January 16, 1906 | | $633.94 |
| Cash received: | | |
| Dues | $2,639.30 | |
| Initiation fees | 860.00 | |
| Pin badges | 29.00 | |
| Electrotypes | 60.00 | |
| Proceedings | 80.00 | |
| Interest on deposits | 43.32 | 3,710.62 |
| | | $4,344.56 |
| Disbursements: | | |
| U. G. Scollay, Treasurer's account | $4.96 | |
| W. M. Mackay, Secretary's account | 905.82 | |
| W. M. Mackay, Secretary's salary | 350.00 | |
| Expenses at annual dinner | 20.00 | |
| A. E. Kenrick, refund | 122.50 | |
| John Gormly, President's expenses | 56.50 | |
| Amer. Soc'y Mech. Engineers' Rooms | 65.00 | |
| J. J. Little & Co., printing | 132.52 | |
| Schoen & Kellerman, printing & stationery | 417.75 | |
| Bormay & Co., electrotypes | 99.64 | |
| International Text Book Co., electrotypes | 37.00 | |
| D. Williams Co., printing | 15.00 | |
| Wm. Kent, editing 1905 Proceedings | 100.00 | |
| Harold Godfrey, reporting annual meeting | 95.00 | |
| G. H. Lambert, reporting summer meeting | 120.05 | |
| Empire State Surety Co., Treasurer's bond | 6.00 | |
| Collections on out of town checks | 1.92 | 2,549.66 |
| Balance on hand | | $1,794.90 |

Respectfully submitted,

U. G. SCOLLAY,
Treasurer.

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On motion the report was accepted and ordered printed in the Proceedings.

President Gormly: Next is the report of the Board of Governors.

Mr. Snyder presented the following report:

## REPORT OF THE BOARD OF GOVERNORS.

The Board of Governors met and organized on January 18, 1906, appointing committees on finance, membership and publication and an executive committee. The various committees have given careful attention to their duties and the Board has met as often as was found necessary during the year. We are able to report a substantial increase in membership and the financial affairs of the Society are in good condition with sufficient funds on hand to pay for the two volumes of proceedings which will be issued, one this month and one in three months. A successful summer meeting was held in Chicago July 19 and 20, 1906, at which it was voted that a change be made in the constitution to provide for local chapters of the Society and that if the members voted favorably on the amendment, permission be granted to the Illinois members to form a local chapter with headquarters at Chicago. A vote was sent out October 30 and 103 votes were cast, 91 being in favor and 12 against the amendment. In accordance with the resolution permission was granted to the Illinois members who formed a permanent chapter on December 3, 1906. We would call your attention to the fact that one-tenth of the membership is from abroad and but one foreign member has been honored by election to an office in the Society, so that if deemed advisable action may be taken to give further recognition to our foreign supporters. We regret the delay in getting out the papers for this meeting, but it was unavoidable owing to the late date some came to hand. Some matters were left over for this Board to dispose of and they have had very careful consideration with final action in accordance with the best interests of the Society and within the powers conferred by the Constitution and by-laws. The request that the Board look into the work of the Fire Protection Association, which has its headquarters in Chicago, was referred to Vice-President T. J. Waters and the Chicago members who have investigated the matter and recom-

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mended that no action be taken. The Board has arranged for the trade press to have access to the stenographer's report of the meetings subject to the corrections of the Secretary.

JOHN GORMLY, Chairman,
W. M. MACKAY, Secretary.

President Gormly: The next is the report of the Committee on Compulsory Legislation, T. J. Waters, Chairman. Is there any report from that committee?

Secretary Mackay: The Secretary has no knowledge of any report being forthcoming. The chairman told me some two months ago that they were working in connection with a law for Illinois. Possibly some of the Illinois members can enlighten us and tell us something of what has or is being done. Perhaps Mr. James Mackay might be able to give us some information.

Mr. James Mackay: There has been quite a little progress made by this Committee on Compulsory Legislation. We are working on a bill which we hope will be passed and which will be presented at this session. We sent the member from Denver some of our data for a bill to be introduced in the Legislature of Colorado. We have nothing to report for the committee, as a committee.

President Gormly: You have no information as to whether the committee intend sending in a report?

Mr. James Mackay: I have heard nothing except that our work, as a committee, is leading to results.

President Gormly: Possibly we may have a report later.

Mr. Barron: I move the report of this committee be delayed until the last day. It is a very important committee—the most important committee we have. I think the report should be delayed until the last day so we can hear from the committee.

The motion was duly seconded and agreed to.

President Gormly: The next report is the report of the Committee on Standards, Mr. William Kent, Chairman, W. F. Wolfe, Prof. J. H: Kinealy, R. P. Bolton and E. F. Capron.

Secretary Mackay: Prof. Kent has sent in a report which he wished me to hand to the other members of the committee. I have only been able to do so within a few minutes. He fully intended to be here, but I received a letter this morning stating that he was unable to be present.

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On motion the consideration of the report of the Committee on Standards was deferred until the last day of the meeting.

President Gormly: The next business in order is the report of the Committee on Tests, Mr. Hoffman, Chairman.

Prof. R. C. Carpenter read the report, as follows:

## REPORT OF THE COMMITTEE ON TESTS.

*To the President and the Members of the American Society of Heating and Ventilating Engineers.*

Gentlemen: The members of your "Committee on Tests" beg to submit the following Report. In doing so the committee wishes to urge, in behalf of its successors, a more generous response from the membership of the Society for points of interest that may be embodied in future reports. The possibilities within such a committee are great, if a hearty co-operation exists, and we trust that some definite and distinctive work be given the committee, and that the Society make this work possible by setting aside ample funds to meet such requirements.

The following outline, covering a series of tests on radiators to determine their relative heating capacity, was given to your committee to be embodied as a part of the report. It is therefore included as an illustration of the *method* employed in the work. The radiators were of different makes, each containing ten 38-inch sections, and the test was for the purpose of determining the comparative value of the radiators as heat transmitters. In determining the extent of outside surface, one inside and one outside section was dealt with for each radiator. Each section thus dealt with was divided by fine lines into elementary areas, and pieces of thin linen paper were cut and fitted to cover each section. The areas of the pieces thus cut were determined by planimeter for the total area of the section.

The arrangement of the testing floor is shown in Fig. 1. The three radiators to be tested were mounted in line at a distance of 7 feet 4 inches apart. They were supplied with steam by a single pipe delivering at the point A, from which point pipes of equal length led to the several radiators. At A, B, C, and D, separators were placed to catch the entrained water. A pressure gauge was attached to the supply piping near A. The presence of these insured a supply of dry steam for each radiator. The condensa-

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tion from each radiator was caught in a covered chamber (E, F and G) with glass gauge attached. The temperature of the air was obtained by means of a separate thermometer suspended below each radiator (H, I). To screen each radiator from accidental air currents a 9 foot wall of cotton muslin was built around them, as shown by Fig. 1. This muslin was set up from the floor several inches to permit a circulation of air to the radiators from below. No horizontal air currents, however, could be detected near the radiators by the most sensitive anemometer.

In preparation for the test, steam was admitted to the radiators

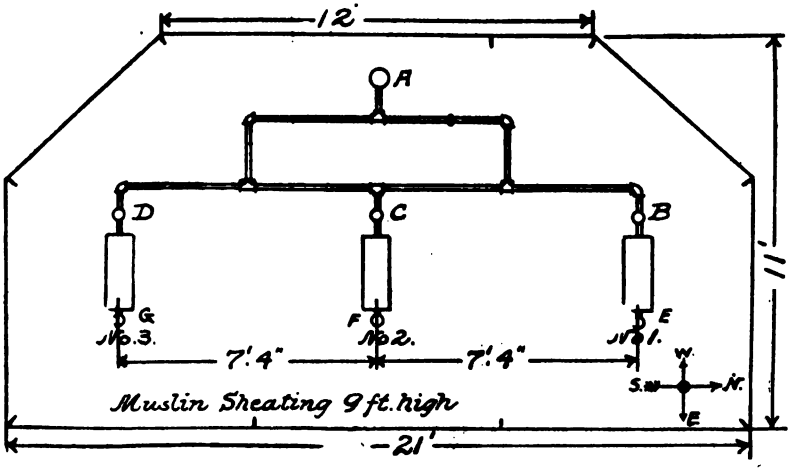


FIG. 1.

at a pressure of 5 pounds gauge, and the condensation was drained off at such a rate as to maintain a constant level in the water glasses. This level was sufficiently low that it insured the radiators being drained at all times. The air cocks were opened a slight amount to insure the discharge of any air which might enter the radiator. After one or two hours of preliminary heating, and when all conditions had been made constant, record observations were taken. A bucket containing a sufficient amount of cold water to make the total weight 6 pounds was had in readiness for each radiator. The outlet valves for each radiator were manipulated until the water levels were at a fixed height, after which, upon signal, the buckets were placed in position to receive the drainage. Observations of pressure and temperature were taken every 15 minutes and the test was continued for one

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hour, after which the buckets were simultaneously moved and weighed. The difference between the initial and final weights gave the condensation for the test and formed the basis from which to determine the amount of heat radiated from each of the several radiators.

To insure that each radiator would get the benefit of the same exposure, providing any difference did exist, due to its location, the test was carried through three times, the position of the radiators being interchanged each time. Thus, if the positions of the radiators were numbered 1, 2 and 3, each radiator in turn occupied each one of these positions. The observed data as taken from each radiator are given in Table 1.

TABLE 1.

OBSERVED RESULTS.

| DATE. | A. | | | B. | | | C. | | |
|---|---|---|---|---|---|---|---|---|---|
| | Condensate per hour. | Position of Radiator. | Temperature. | Condensate per hour. | Position of Radiator. | Temperature. | Condensate per hour. | Position of Radiator. | Temperature. |
| | I. | II. | III. | IV. | V. | VI. | VII. | VIII. | IX. |
| April 17..... | 12.375 | 3 | 72.0 | 11.875 | 1 | 70.2 | 12.688 | 2 | 70.2 |
| April 18..... | 12.063 | 1 | 69.8 | 11.688 | 2 | 69.6 | 12.750 | 3 | 71.2 |
| April 19..... | 11.220 | 2 | 78.4 | 11.125 | 3 | 78.6 | 11.688 | 1 | 78.6 |
| Total..... | 35.658 | ..... | 220.2 | 34.688 | ..... | 218.4 | 37.126 | ..... | 220.0 |
| Average... | 11.886 | ..... | 73.4 | 11.563 | ..... | 72.8 | 12.375 | ..... | 73.3 |

From Table 1 the following points of general interest may be taken:

| Name of Radiator. | A. | B. | C. |
|---|---|---|---|
| Weight in pounds..... | 362. | 345.5 | 318.5 |
| Actual superficial area. ..... | 52.49 | 50.69 | 50.10 |
| Gauge pressure during test..... | 5. | 5. | 5. |
| Temperature of surrounding air..... | 73.4 | 72.8 | 73.3 |
| Difference of temperature between air and that of steam ..... | 153.6 | 154.2 | 154.7 |
| Condensation per hour..... | 11.886 | 11.563 | 13.375 |
| Heat (B. T. U.) radiated per degree difference of temperature per square foot of surface per hour. | 1.41 | 1.41 | 1.53 |

The above calculations refer to exterior surface of the radiator only, as no attempt was made to determine the extent of interior surface exposed to the steam.

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The following abstract was taken from a thesis entitled "An Efficiency Test of The Merchants' Heating and Lighting Plant of LaFayette, Indiana," conducted by Messrs. E. Faris, L. J. J. Owens, and C. J. Peck, senior students of Purdue University, under the supervision of the Chairman of this committee. The test included the electric lighting plant, boiler plant, heating plant and the conduit. The Committee believes that an abstract of the report covering the heat losses from the conduit might well be added as a part of this report.

The system under consideration is a two-pipe hot water system, with flow and return in the same conduit. The conduit is built up of three-ply one inch boards insulated from each other

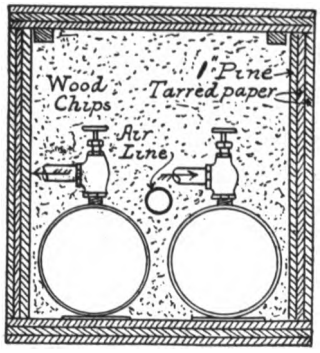


FIG. 2.

by tarred paper, the interior of the conduit being filled with wood chips and then covered with crude oil, all as shown in the section Fig. 2. The conduits were laid in 1902 and when the test was conducted they were considered to be in a fair state of preservation.

The capacity of the system was about as follows:

| | | |
|---|---|---|
| Total square feet of radiation | | 118000. |
| Length of conduit in feet. | 10-inch main | 450. |
| " " " " " | 8-inch " | 1200. |
| " " " " " | 6-inch " | 4700. |
| " " " " " | 5-inch " | 1700. |
| " " " " " | 4-inch " | 6800. |
| Total length of all conduit | | 14850. |
| Total length of flow and return mains | | 29700. |

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During the test on the conduit the following average conditions prevailed:

| | |
|---|---|
| Duration of first test on conduit, in hours | 10. |
| Pressure in flow main, pounds per square inch | 60.6 |
| Pressure in return main, pounds per square inch | 32.23 |
| Barometer, in inches of mercury | 29.5 |
| Temperature in flow main at the plant, degrees F | 158.36 |
| Temperature in return main at the plant, degrees F | 140.66 |
| Outside temperature in degrees | 31.2 |

To determine the heat losses from the conduit, a Pitot tube was placed in the main 10-inch Flow pipe at the Plant and a similar tube, Fig. 3, was placed at point X in the 8-inch Flow

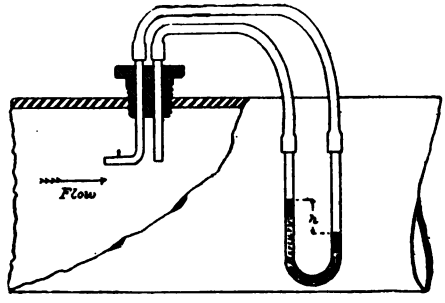


FIG. 3.

pipe at a distance of 1582 feet from the first tube. The velocity of the water passing each point was then calculated from the observed data. These readings are shown in Table 2.

TABLE 2.

| TIME. | PITOT TUBE NO. 1. | | | PITOT TUBE NO. 2. | | |
|---|---|---|---|---|---|---|
| | Height in Ins. Hg. | Temperature. | Cor. Temp. | Height in Ins. Hg. | Temperature. | Cor. Temp. |
| 10.15 | 1 7/16 | 151 | 153 | 1/4 | 146 | 149 |
| 10.30 | 1 1/4 | 150 | 152 | 5/16 | 146 | 149 |
| 11.30 | 1 7/16 | 152 | 154 | 1/4 | 147 | 150 |
| 12.30 | 1 7/16 | 156 | 158 | 1/4 | 151 | 154 |
| 1.30 | 1 1/4 | 155 | 157 | 5/32 | 151 | 154 |
| 2.30 | 1 1/4 | 159 | 161 | 5/16 | 156 | 159 |
| 3.30 | 1 1/4 | 159 | 161 | 1/4 | 155 | 158 |
| 8.30 | 1 1/8 | 160 | 168 | 5/16 | 156 | 159 |
| Total..... | 11 1/2 | 1242 | 1258 | 2 1/32 | 1208 | 1232 |
| Average.... | 1.4765 | 155.2 | 157.2 | .2539 | 151 | 154 |

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The results obtained from the above readings are as follows:

| | |
|---|---|
| Velocity of the water at the plant in feet per second | 7.336 |
| Velocity of the water at the point X in feet per second | 3.046 |
| Amount of water passing point X in gallons per second | 7.95 |
| Amount of water passing point X in pounds per second | 64.83 |
| Drop in temperature from plant to point X, in degrees | 3.2 |
| Drop in temperature per 1,000 feet of conduit, in degrees | 2.022 |
| B. T. U. lost by water from plant to point X, per hour | 746840. |
| B. T. U. lost by water per 1,000 feet of conduit | 472090. |
| B. T. U. lost by one pound of water per 1,000 feet | 2.022 |
| Per cent. of heat gained in the plant, lost per 1,000 feet of conduit | 11.4 |

The loss from the Return main would be less than the above because of somewhat lower temperature of the water. Suppose this loss to be only 8.6 per cent. (a very safe figure), then the total heat loss from the conduit per 1000 feet is 20 per cent.

The above figures may be considered of value only for the one condition as stated. Conduits containing pipes of other sizes would probably have heat losses varying greatly in amount from that shown on the one carrying the 8-inch pipe. The results, however, do show that in the average conduit, with pipes insulated as these are, there is a considerable loss of heat during transmission.

Respectfully submitted,

J. D. HOFFMAN,
S. G. NEILER,
W. G. SNOW,
H. A. LOEB,
C. R. BRADBURY,
Committee.

On motion the report was received and ordered to be filed.

President Gormly: Next is the report of the Special Committee on Standard Sizes of Steam and Return Mains.

The report was read by Mr. J. A. Donnelly.

## REPORT OF COMMITTEE ON STANDARD SIZES OF STEAM AND RETURN MAINS.

The Committee on Standard Sizes of Steam and Return Mains beg to submit the following report, to be presented to the Society through the Committee on Standards:

" As we have received but one answer to the list of questions

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sent out since the summer meeting, and as that answer did not materially change the average compiled at that time, they regret to report that they have no additional data to add to their preliminary report.

"In regard to the recommendation of a standard, their investigations have led them to the conclusion that the use of such a velocity as will require a difference of pressure of *not more* than one ounce to one hundred feet in straight pipe to maintain it, represents, as near as they can at present ascertain, the best average practice in proportioning the sizes of steam and return mains."

Respectfully submitted,

J. A. DONNELLY,
HUGH J. BARRON,
FRANK G. MCCANN.

On motion the report was received and discussion on it deferred until the evening's session.

President Gormly: The next business is the report of the Special Committee on Hot Water Heating.

Mr. Lewis read the report of the Committee.

On motion the report was accepted with thanks, and ordered printed for distribution and the committee continued.

President Gormly: The next business is the report of the Committee on Steam Heat for Small Buildings, Mr. J. J. Blackmore, Chairman.

Mr. J. J. Blackmore: The committee that has just reported has made the report of this committee seem rather small. This committee has no report, owing to the fact it made a report at the semi-annual meeting showing what it was doing and what it proposed to do. At the time we prepared a circular, and the data that were gathered were included in the paper of the Committee on Standards. The report of this committee is short.

## REPORT OF SPECIAL COMMITTEE FOR GATHERING INFORMATION ON STEAM HEATING FOR SMALL BUILDINGS.

New York, January 22, 1907.

Your Committee beg to report that since the semi-annual meeting when the preliminary report was handed in, that

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the circulars then printed were sent to the various members, but it is to be regretted that only two replies were received.

These replies, however, gave the views of the members sending them in very fully. These papers, together with any other information the Committee was able to gather, were forwarded to Professor Kent, Chairman of the Committee on Standards, in November last, for his Committee to make up a report upon them.

Respectfully submitted,

J. J. BLACKMORE,
B. H. CARPENTER,
A. M. FELDMAN,
Committee.

President Gormly: You have heard the report of the committee. What is your pleasure?

Mr. Chew: It seems to me this is a report of progress. The work of the three different committees appointed last January has justified their appointment. I move this report be received and the committee continued.

The motion was agreed to.

President Gormly: The next business is the appointment of tellers. I will appoint W. S. Washburn, J. H. Brady and G. B. England as tellers to report at the session to-night.

Secretary Mackay: Before new business is taken up, I would state that it has been suggested, as we are the first national society to hold its annual convention in the new Engineering Building, that it might be in order to have an inspection of the building and its heating apparatus, and it has been suggested that between 10 and 11 o'clock to-morrow morning will be a good time to inspect the building and apparatus.

I have invitations relative to our summer meeting from different points—from Milwaukee, Niagara Falls, Buffalo, Jamestown and Atlantic City.

## NEW BUSINESS.

Mr. Munroe: I think that this Society should give sufficient of its funds to pay the Illinois Chapter for furnishing each member with a copy of the doings of their meetings. I suppose they will have their papers printed and we ought to derive benefit from them. Unless this is done we will never

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hear of anything done in that Chapter. If there are such papers, I think we should have them. I won't offer a motion until we find out.

Mr. Hale: We understand in reference to papers that we have no right to publish papers until they are submitted to the Board of Governors. It is our thought that we pass papers to the Secretary of the Society. We propose to publish nothing which we have no right to.

President Gormly: You are correct.

Mr. Barron: I am glad Mr. Munroe has made this remark, because I have misgivings in reference to this Chapter matter. It might ultimately interfere with the workings of this Society. There is no harm in our threshing it out and having an understanding as to what we are aiming at. In New York we have no intention of having anything but a social meeting—not a technical meeting in any sense, and, yet, it might develop into a separate and distinct Chapter or organization, sub-organization of this Society. It is well for us to look ahead and see what we are doing. We want to head off any trouble in the future. But I do not think there is any danger so long as we have a clear understanding at the start.

Mr. James Mackay: There is nothing that can be done by a Chapter that can in any way interfere with the parent body, and the Chapter can do nothing but what will redound to the advantage of the parent body, nothing except that which is sanctioned by the Board of Governors of this body, and, whatever is done is done for the benefit of the whole, that is, for the original parent body.

President Gormly: There is nothing before the body. Is there any new business to be presented?

On motion the meeting adjourned to meet at 8 P.M.

## First Day—Evening Session.

(Tuesday, January 22, 1907.)

The meeting was called to order by President Gormly at 8.30 P. M.

President Gormly: The first order of business is the report of the tellers. The tellers will please report.

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Mr. Washburn, on behalf of the tellers, presented the following report:

REPORT OF TELLERS.

Total vote cast.....151
Defective ..... 3

*President.*

Reginald P. Bolton..... 48
C. B. J. Snyder.....100

*1st Vice-President.*

James Mackay.....104
T. J. Waters..... 42

*2d Vice-President.*

Wm. G. Snow..... 85
Jas. D. Hoffman..... 60

*Secretary.*

Wm. M. Mackay.....135
Thos. Barwick..... 12

*Treasurer.*

U. G. Scollay.....111
Frank P. Blodgett..... 35

*Board of Governors.*

R. C. Carpenter.....109
Robt. E. Atkinson..... 81
Frank K. Chew.....116
Edmund F. Capron..... 83
B. F. Stangland..... 76
Albert B. Franklin..... 83
John F. Hale..... 60
B. H. Carpenter..... 54
O. M. Feldman..... 24
Wm. H. McKiever..... 36

Submitted by Tellers,

WM. S. WASHBURN,
J. H. BRADY,
G. B. ENGLAND.

President Gormly announced the result and declared the successful candidates elected.

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President Gormly: The first business in order is the reading of a paper: "Standard Sizes of Steam Mains," by J. A. Donnelly.

Mr. Donnelly read the paper.

President Gormly: The paper is before you for discussion. There is considerable matter in that paper and I hope we will have a free discussion.

Prof. Carpenter suggested that discussion on the foregoing paper be postponed until after the reading of the next paper, to which there was no objection.

President Gormly: The next paper is "Carrying Capacity of Pipes in Low Pressure Steam Heating," by Wm. Kent.

The paper was read by Prof. Carpenter.

The two papers were discussed by Prof. Carpenter and Messrs. Donnelly, Bolton, Baldwin and Taggart.

President Gormly: Is there any further discussion? (There appeared to be none.) If not, we will go to the topics. Topic No. 1: "Relation of steam and return connections to horse-power in heating boilers." I would like to hear something on that topic. (No response.)

If there is nothing to be said, we will proceed to topic No. 2: "Size of safety valve for heating boilers, under varying pressures up to ten pounds." This is open for discussion.

(As the hour was getting late there was no discussion.)

President Gormly: We have finished our work for the evening and adjournment is in order, to meet at 2 o'clock to-morrow afternoon.

On motion the meeting adjourned.

## Second Day—Afternoon Session.

(Wednesday, January 23, 1907.)

The meeting was called to order by President Gormly, at 2.30 P. M.

President Gormly: The first business in order this afternoon is the reading of a paper, entitled: "Temperature for Testing Indirect Heating Systems," by W. W. Macon.

The paper was read in abstract by Mr. Macon and discussed by Mr. Donnelly.

Secretary Mackay: I want to announce on behalf of the Reception Committee, that the Committee will be glad to give any in-

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formation on any points of interest in New York to the visiting members and guests. (Names of committee read.)

Mr. Chew: We have another paper here, a supplementary report of the committee appointed to collect data on furnace heating, sent in by Prof. Kent to the Committee on Standards.

(Mr. Chew distributed the paper referred to—Supplementary report of Committee on Furnace Heating.)

Mr. Wolfe: I have the report containing the notes sent to the Committee on Standards by Prof. Kent, which I do not think can be intelligently discussed now, but can be when Prof. Kent is present. I suggest that it be referred to the Board of Governors and that it be printed and submitted at the mid-summer meeting.

Mr. Chew: I move it be referred to the Board of Governors, to be printed, if deemed advisable. It is not a report. It is notes to the Committee on Standards. On account of the valuable information it contains I did not think we ought to let the thing escape. This does not tie the Society to anything or ask the endorsement of it, but brings it so it can be read and understood.

The motion was duly seconded and agreed to.

President Gormly: Are there further remarks? If not, we will go on to the next subject: "The Derivation of our Constants for Building losses," by R. C. Carpenter.

Prof. Carpenter then read the paper.

President Gormly: The next topic for discussion is topic No. 3: "In the so-called fan or forced blast system of heating, how should the amount of heating surface in the tempering and heating coils be determined in view of the variation in practice?" The topic is now before you. (No discussion.)

President Gormly: Topic No. 4: "Fuel required to operate a district heating and electric plant combined using exhaust steam for heating, as compared with a heating plant alone using direct steam."

(No discussion.)

President Gormly: We will proceed to topic No. 5: "The air space required through hot-blast heaters."

Mr. Chew: There are some members especially interested in the fan heating question, and, if they are appointed on a committee to collect data, I feel the Society will get information. This should not be referred to the Committees on Standards or Tests, the graveyard of the past, where it would soon have moss

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on it. I move the President appoint a special committee to collect data on fan-blast heating.

Mr. Wolfe: If there is a committee appointed to give you reliable data there should be some money to go with it. When we try to get fan-blast data we have to depend largely upon the fan blast manufacturers. That is the starting point, and we check back and find they are wrong. It takes a lot of time and considerable money to carry through a series of experiments that are complete enough for us to put them in our books as record tables, that any one may turn to and work by and be sure they are correct. There are plenty of institutions throughout the United States at the present time, capable, willing and glad to make certain tests for a very moderate consideration, inasmuch as it forms a part of the teachings of the engineers in the departments. Figures from such a source can be checked back in tables and formulas, and where they differ they can be tried again to find which is right and which is wrong. In course of time our proceedings will show a set of tabulations, made especially for the purpose and paid for, done by competent and disinterested people, and we will have something valuable.

Mr. Chew: I favor this—that the committee on this special work report to the Committee on Standards. There are two reasons why I object to spending money. We have other uses for our money that are important and we cannot afford to pay any considerable amount of money.

Mr. James Mackay: Mr. Chew's motion, as I understand it, was to collect data, that is, new data as applying to present practice. These data are just as valuable to heating engineers as any other information that we may obtain through special committees. The data that have been collected, as applying to present practice all over this country, tabulated and placed in accessible form, I think will be very valuable.

Mr. Barron: I want to amend, that this committee formulate and analyze the blower data in our proceedings up to date.

Secretary Mackay: A few years ago a certain amount was appropriated for the Committee on Tests and not drawn on. Prof. Kent made an offer a year ago, that if any member wanted anything tested, if he would send it to the Syracuse University he would have a test made. That has been offered by Prof. Carpenter, Prof. Kent and Prof. Hoffman. Our special committees

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have gathered for us a large amount of valuable information free of cost to the Society. The Society has not paid for any of it. And a committee appointed to collect data would bring us a lot of valuable information, as the hot air committee, and the hot water committee, and the steam committee, and the size of mains committee have done.

Prof. Carpenter: We have in our proceedings a good many tests of apparatus on record, in order to find what laws apply. For instance, to find what size of air duct gives us best results, either the blower heating system or the coils, we have to build a lot of coils with different air systems. And the cost of building them in different ways represent an immense amount of money. It seems to me at present, we should pass this motion just as it is. Afterwards, if there is opportunity for making investigation and tests, why, I hope it will be carried through.

I might say in connection with tests of heat transmission, this is one of the tests I have started out with this year, to check up some of Peclet's work in heat transmission through windows and walls. I started in on a small scale, but still a larger scale than Peclet used. I have no doubt I shall substantially check his if I do not make a mistake.

Mr. Chew: I believe, when all these different reports are gone over by the Committee on Standards, after they have come in and accumulated the Committee will be able to formulate some standards from the information they contain. The Committee of Standards would be only one to formulate conclusions.

President Gormly: The motion is that a committee of five be appointed to analyze blower or fan-blast heating data in our proceedings to date, also, any blower data that we get from any other place, and report to the Committee on Standards.

The motion was agreed to.

President Gormly: We have a topic handed in but not printed:

1. What amount of water per 100 feet of radiation should a cast iron steam boiler hold to give the best results? Is 6.5 gallons enough? If not, why not?

2. What should be the temperature in the radiators of a hot water apparatus when the water leaves the boiler at 120, 140, 160, 180 degrees? Should it be less or more than 10%?

Secretary Mackay: I presented a paper a number of years ago

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on that subject, and, after investigating a number of them, my conclusion was the average hot-water apparatus will show a drop of nearer 20 degrees.

Secretary Mackay here made announcements relative to reception between 6 and 8 and the dinner at 8 P. M.

On motion the meeting adjourned to 10.30 A. M. on Thursday.

## THIRD DAY—MORNING SESSION.

(Thursday, January 24, 1907.)

The convention was called to order by President Gormly at 10.50 A. M.

President Gormly: The first business in order is the reading of a paper: "Comparison of Quick Ciculating Systems of Hot Water Heating," by C. Guitton, St. Etienne, France, by request.

Mr. B. H. Carpenter will please have the kindness to read that paper.

Mr. B. H. Carpenter read the paper.

The paper was discussed by Prof. Carpenter and Mr. Hopkins.

President Gormly: Next is a paper: "Systems of Heating Railway Cars with Hot Water," by R. C. Carpenter.

The paper was discussed by Messrs. Davis, Barron, Baldwin and Jellett.

President Gormly: The next topic for discussion is: "The relative healthfulness of direct and indirect heating systems."

The topic was discussed by Messrs. Franklin, Baldwin, Chew, Schaffer and Brady.

President Gormly: Topic No. 8: "Rated surface of radiators versus actual surface."

The topic was discussed by Messrs. Wolfe, Markley, Baldwin, Barron, Brady and Thomson.

On motion the meeting adjourned.

## THIRD DAY—AFTERNOON SESSION.

(Thursday, January 24, 1907.)

The meeting was called to order by President Gormly at 3.30 P. M.

President Gormly: Gentlemen, the first business in order for the afternoon, is the reading of a paper: "The relation of the

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force of gravity to some of the economics of heating," by Dr. J. M. W. Kitchen.

The paper was read by Dr. Kitchen and discussed briefly by Mr. Hale.

President Gormly: The next business in order is the installation of officers. I will appoint as a committee to escort the newly elected officers to the platform, Stewart A. Jellett and Hugh J. Barron.

(Said committee here conducted C. B. J. Snyder, the newly elected President, to the platform.)

President Gormly: (Addressing Mr. Snyder.) I receive you as the highest officer of this association. You will find the position a pleasure. Your duties will be to supervise the general management of the association. I believe you are familiar with these duties and it is hardly necessary to explain. Are you ready to accept the office?

President-elect Snyder: I am.

President Gormly: Gentlemen, you have duly elected Mr. C. B. J. Snyder, President. (Applause.)

The committee then conducted to the platform Mr. James Mackay, elected First Vice-President, Mr. William G. Snow, elected Second Vice-President, Mr. William M. Mackay, re-elected Secretary, Mr. E. G. Scollay, re-elected Treasurer, and Messrs. F. K. Chew, E. F. Capron and A. B. Franklin, newly elected Directors, and they were duly installed in office.

President Gormly: Gentlemen, I thank you for the support you have given me through my administration. I trust you will extend fully and with one accord that support to Mr. Snyder. (Applause.)

(Mr. Snyder in the chair.)

President Snyder: Gentlemen, I pledge to you a continuance of the high standing which this Society has gained under previous presidents and various officers.

Before continuing with the order of business as laid down on the program, I wish to make this announcement: The Society has seen fit to cause to be appointed a Committee on Fan and Blower data.

As this committee, I will appoint:

William G. Snow, Chairman, R. C. Carpenter, J. H. Kinealy, F. R. Still, and J. H. Brady.

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All committees, both regular and special, are continued until further notice.

President Snyder: We have on our program topic N. 9: "Durability of steel and wrought iron pipes used as returns for exhaust steam heating, also when high pressure steam free from oil is used."

Does any one desire to be heard upon this topic?

If not, we will proceed to the next one: "Expansion of pipes due to heat from steam, high pressure 100 pounds and upward, and 10 pounds and under." This subject is before you. (No response.)

We will take up No. 11: "Advantages of standard dimensions of radiator valves and connections." (No response.)

President Snyder: I will ask the Secretary to read the invitations for the summer meeting.

Secretary Mackay: I have invitations from Milwaukee, Niagara Falls, Buffalo, Jamestown and Atlantic City. Mr. Bennett, from Niagara Falls is here, and wishes to address the meeting.

Mr. Brady: While I am the only representative here from Kansas City, I want to extend an invitation for you to hold your semi-annual meeting in that city—Kansas City, Missouri. I assure you all that should you decide to come we will show you the best time you ever had. Kansas City is noted for its hospitality and you will find men there high up in the profession who are always willing to "show you." I would like you to consider Kansas City.

Mr. Bennett of Niagara Falls then addressed the Society urging the advantages of that city as a place for the summer meeting.

President Snyder: I beg to say that Art. II, Sec. 1, says that the designation of the place for the semi-annual meeting is in the hands of the Board of Governors. It has heretofore been our policy to obtain so far as possible an expression of opinion from those present as to their preferences in the matter, that the Board may be fully acquainted with the desires of the Society. If there is any one here who desires to give an expression of opinion, we will be glad to hear him.

Mr. Hale: It has been suggested that we consider the possibility of members coming into the Society. While we are close (Chicago) to Milwaukee, there are not enough in Milwaukee to

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form a Chapter. Illinois has a Chapter and as a member of the Chicago contingent I suggest we consider Milwaukee.

Mr. Chew also spoke in favor of Milwaukee or some other western city.

President Snyder: It might be well for us to have an expression of opinion.

(A viva voce vote seemed to indicate Milwaukee.)

Mr. Brady: I am in favor of leaving this entirely with the Board of Governors.

President Snyder: We will consider the subject closed.

We will go back and take up No. 11: "Advantages of standard dimensions of radiator valves and connections." The topic was discussed by Mr. Donnelly.

Mr. Chew: I move the Committee on Standards be requested to confer with the committee of the Steam Fitters' Association on this matter and lend such assistance as they can. (Seconded and carried.)

President Snyder: The next topic is No. 12: "Should the guarantee of efficiency be assumed by the heating engineer who designs the apparatus, or the heating contractor who installs it?" The subject is before you.

The topic was discussed by Mr. Brady.

Mr. Barron: I think earlier in the sessions there were motions made that certain matters should be referred to the last day. I move that such matters be referred to the Board of Governors for action.

The motion was agreed to.

Secretary Mackay: There is the report of the Committee on Compulsory Legislation. (No report, some of the committee having left.)

Mr. Donnelly: Referring to the matter of the National Fire Protective Association, I wrote to the American Society of Mechanical Engineers and the American Society of Architects, and received letters which I referred to the Board, through President Gormly. Nothing definite has come from that recommendation.

I move the Secretary and Board of Governors confer with the American Institute of Architects and with the American Society of Mechanical Engineers, and if possible learn from them the work that is being carried on by the National Fire Protective

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Association and give us the information so we can consider joining it as a body. It seems to me we might represent the heating apparatus in that body, also the protection of steam pipes and ventilating flues. The contractor very often has disputes with the Board of Fire Underwriters in regard to protecting steam pipes. It seems to me there is a good deal of dissatisfaction in the heating trade in regard to the requirements of the Board of Fire Underwriters.

Secretary Mackay: This was handed in by Mr. Donnelly to the Board of Governors.

Mr. Donnelly: I think we can secure information from the American Institute of Architects and from the American Society of Mechanical Engineers. I made this motion requesting them to look it up.

Secretary Mackay: There is to be something done between this Society and the Master Steam Fitters' Association. I simply wanted to put this before you to show the action of the Board, and, also, the consideration of the Chicago members of the Board. In Chicago they took this matter up, and Mr. Waters turned it over to his assistant, and they considered the matter. I was there when a vote was taken by the local Chapter that they report to the national body that it be not wise to consider the matter. Mr. James Mackay was present at that meeting.

Mr. Donnelly's motion was seconded and carried.

Mr. Franklin: I should like to make a motion relative to topic No. 12: That it is the sense of this Society that guarantee of efficiency should be assumed by the heating engineer who designs the apparatus.

President Snyder: Do you think it wise to press that motion with so few members present? May I suggest that this topic be continued for our next meeting, to come up and be discussed where we can have full expression and then have a decision reached. Mr. Franklin, will you withdraw that motion?

Mr. Franklin: I feel this way in regard to this matter. I am always willing with every apparatus I design to be responsible that it be carried out as designed. I believe that will be the reply of every engineer. I do not wish, however, to press anything upon this Society that would be construed as unfair, and if it is the sense of the meeting it is not the proper time to present this subject and get the sense of this Society, I am willing to with-

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draw it. Otherwise I should like to have an expression of the Society.

Mr. Scollay: I move the question be laid over until the next annual meeting, that it come up on the first day when we have a full attendance, when it will give opportunity for these consulting engineers to be present and defend themselves.

Mr. Barron: I think it is a very serious and important question, and I appreciate the point of view that we ought to have a number of consulting engineers to talk upon it. But it is important that expression of the opinion of this Society should go on record because we might accomplish the result Mr. Franklin is aiming at. My suggestion would be that it is the sense of this meeting that the Board of Governors take some action in getting the views of this organization on this question. In other words, that it is the sense of this meeting that the consulting engineer should be wholly responsible, and with that addition it be referred to the Board before that expression of opinion is expressed publicly or published in the papers. We should not go on record without a full consideration of the subject.

Mr. Scollay: I withdraw my former motion and substitute this motion: I make a motion that it is the sense of this annual meeting of 1907, that the matter in question be referred to the Board of Governors, with a strong recommendation from this Society that they present it to the individual members of the Society, with proper blanks to vote on by mail, so they can be received in time for an expression at the annual meeting.

Mr. Jellett: I suggest that as this discussion will be in type, it might be set up and rough copies made and sent to all the members by mail, asking them to read the discussion, thus enabling them to vote more intelligently pro or con.

Mr. Scollay's motion, having been duly seconded, was agreed to.

On motion the meeting adjourned.

List of Members and Guests present at Thirteenth Annual Meeting, January 22, 23, and 24, 1907:

MEMBERS.

| | | |
|---|---|---|
| Addams, Homer. | Barr, Geo. W. | Bernhard, John B. |
| Andrus, Newell P. | Barron, Hugh J. | Blackmore, J. J. |
| Armstrong, Chas. G. | Barwick, Thomas. | Boylston, John. |

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BLODGETT, FRANK P.
BOLTON, R. P.
BRADY, JOS. H.
BRENNAN, JOHN S.
CAPRON, EDMUND F.
CARPENTER, B. H.
CARPENTER, R. C.
CARPENTER, R. R. M.
CHEW, FRANK K.
CLARK, GEO. W.
CONNOLLY, JOHN A.
CRANE, H. D.
CRAWFORD, GEO. H.
CRYER, T. B.
DAVIS, BERT C.
DAVIS, JAS. H.
DENNY, EDW. B.
DILL, J. B., JR.
DONNELLY, G. A.
DORNHEIM, G. A.
DRISCOLL, WM. H.
EDGAR, A. C.
ENGLAND, GEO. B.
FEBREY, E. J.
FELDMAN, A. M.
FRANKLIN, A. B.
GALLOUP, JOHN O.
GEIGER, AUG.
GOMBERS, H. B.
GORMLY, JOHN.
GRAHAM, JOS.
HALE, JOHN F.
HANKIN, RICHARD.
HARVEY, ANDREW.
HOFFMAN, J. D.
JELLETT, STEWART A.
JOSLIN, H. A.
KELLOGG, C. V.
KENRICK, A. E.
KLEMM, J. GEO., JR.
LEWIS, S. R.
LISK, J. P.
MACKAY, JAS.
MACKAY, W. M.
MALLORY, H. C.
MARTIN, HARRY S.
MCARTHUR, CHAS. D.
MCCANN, FRANK G.
MCKIEVER, WM. H.
MERRITT, JAS. H.
MOBLEY, EDW. S.
MONASH, MARK E.
MUNROE, E. K.
O'HANLON, GEO.
OSBOURN, M. P.
PAYNE, JOHN A.
RILEY, C. L.
RITTER, H. H.
SCHAFFER, J. P.
SCOLLAY, U. G.
SEWARD, P. H.
SHANKLIN, J. R.
SMITH, H. A.
SNOW, WM. G.
SNYDER, C. B. J.
STANGLAND, B. F.
STIBBS, GEO. H.
STOCK, EDW. L.
SWITZER, WM. H.
TALCOTT, R. B.
TERAN, CESAR.
THOMSON, T. N.
TRASCHEL, J. C. F.
TJERSLAND, ALF.
VROOMAN, WM. C.
WASHBURN, WM. S
WEBSTER, WARREN.
WILSON, H. A.
WING, L. J.
WOLFE, W. F.

## GUESTS.

APPLETON, W. S.
ARMAGNAC, A. S.
BAHN, E. L.
BALDWIN, N. J.
BARTON, H. R.
BAUMER, D.
BAUMER, H. E.
BENDER, A.
BLACK, JOHN.
BOARDMAN, H. G.
BURNHAM, W. S.
CALLISTER, F. B.
CARPENTER, RAYMOND.
COMMER, F. M.
COREY, M. L.
DENNY, R. C.
FAY, CHAS. H.
FOOTE, J. H.
FRANKLIN, LAWRENCE.
FUNDINGER, C. G.
GORDON, C. E.
HALLER, J. M.
HEDRICK, P. L.
HOPKINS, C. C.
HURD, B. N.
ILLIG, L. J.
JENNINGS, GEO. E.
JOHNSON, WM. E.
KAISER, M. L.
KIELLY, T. J.
KINNEAR, R. H.
LAHAN, J. D.
LE COMPTE, W. A.
LINCOLN, C. C.
LINDEMUTH, N. R.
LINKER, P. G.
MACON, W. W.
MAYO, R., JR.
MCCOY, C.
MORRISON, CHAS.
MOSKE, O. E.
MOSNER, JOHN.
MOSSBRUGGER, A. F.
MOTT, GEO. T.
MUNRO, WM. R.
NUGENT, T. A.
OAKES, F. R.
OLSTEAD, E. J.
PURDY, F. G.
QUACKENBOSS, L. H.
RADCLIFFE, W. H.
RICHARDSON, F. P.
ROGERS, WM. A.
SCHROEDER, N. C.
SCHROEDER, W. L.
SCOTT, CHAS. E.
SCOTT, WINFIELD.
SINGER, E. F.
STEWARD, I.
SWAN, E. R.
THOMPSON, WALTER.
TIMLER, O. P.
VANDEVEER, E. P.
WEIDER, F. J.
WETMORE, R. B.
WILSON, A. A.

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The Cup presented to Past President Alfred E. Kenrick at the Annual Dinner of The American Society of Heating and Ventilating Engineers, January 23, 1907, "In Recognition of a Service Rendered."

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# PAPERS

OF THE

# THIRTEENTH ANNUAL MEETING,

New York, January 22, 1907.

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## CLXX.

# STANDARD SIZES OF STEAM MAINS.

BY JAMES A. DONNELLY.

(Member of the Society.)

The subject of the proper sizes of steam mains has usually been discussed with all, or almost all, of the different elements considered as variable.

If as many of the variable elements as possible are eliminated very much progress may be made toward agreement.

It has been suggested that smaller pipes might be used when the pressure of steam is increased, but there seems to be no good reason why a larger drop should be desired when a higher pressure is to be used. It is certain that the saving in first cost would not warrant the resulting decrease in efficiency.

The change in the density of steam, and resulting friction, as pressures somewhat above or below atmosphere are used, is very nearly offset by the changing rate of condensation, due to the change in temperature; so that the amount of direct radiation that may be put upon pipes for a uniform drop is practically the same for reasonable differences in pressures, as will be seen by the table on the next page.

The comparatively slight difference that does exist favors the practice of an increase of radiation as the pressure is reduced, rather than the opposite, as has been usually maintained.

If a plant is designed to run at ten pounds pressure in the coldest weather, and with quite a large drop, it could not be considered a successful piping system if it failed to heat all radiators with a very slight pressure in mild weather; or if it did not work properly when steam was being raised or lowered. Therefore it would seem logical to figure all steam mains with steam at substantially atmospheric pressure.

It has sometimes been stated that different methods of heating might call for different standards of pipe sizes, but as it is impossible for any method, no matter how perfect, to work contrary

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CAPACITY OF STEAM MAINS WITH VARYING PRESSURES.

| Gauge Pressure. | Tem. | B. T. U. Per Sq. Foot Per Deg. | B. T. U. Per Sq. Foot Rad. Sur. | Lbs. Steam Per Sq. Foot Rad. Sur. | Sq. Ft. Rad'n. 10"-Pipe 1 oz. Drop. | Velocity in Feet Per Second. |
|---|---|---|---|---|---|---|
| 26" V. .... | 126° | 1.768 | 99 | .0965 | 28,000 | 235. |
| 24" " .... | 141° | 1.817 | 129 | .127 | 25,700 | 193. |
| 22" " .... | 153° | 1.88 | 156 | .155 | 24,100 | 170. |
| 20" " .... | 162° | 1.9 | 174 | .174 | 23,800 | 152. |
| 18" " .... | 170° | 1.95 | 195 | .196 | 23,100 | 140. |
| 16" " .... | 177° | 1.99 | 213 | .215 | 22,600 | 130. |
| 14" " .... | 183° | 2.03 | 230 | .234 | 22,500 | 123. |
| 12" " .... | 188° | 2.06 | 243 | .247 | 22,400 | 116. |
| 10" " .... | 193° | 2.08 | 256 | .262 | 22,325 | 110. |
| 8" " .... | 198° | 2.09 | 268 | .275 | 22,270 | 105. |
| 6" " .... | 202° | 2.1 | 277 | .285 | 22,225 | 101. |
| 4" " .... | 206° | 2.11 | 287 | .296 | 22,180 | 97. |
| 2" " .... | 209° | 2.111 | 293 | .303 | 22,150 | 93. |
| 0 lbs..... | 212° | 2.112 | 300 | .310 | 22,000 | 90. |
| 5 " .... | 228° | 2.22 | 351 | .368 | 21,600 | 80. |
| 10 " .... | 240° | 2.26 | 384 | .406 | 21,000 | 72. |
| 15 " .... | 250° | 2.28 | 410 | .438 | 20,600 | 65. |

to the laws that govern the flow of steam in pipes, and as an increase in velocity is always attended by a decrease in efficiency, the same standard of sizes of steam mains is advisable with all methods of circulation.

Many attempts have been made to introduce new and improved methods, a lower steam pressure and a smaller standard of pipe sizes simultaneously; but if the method is successful it undoubtedly meets with its best success when the regular sizes of steam mains are not reduced.

It has been suggested that the maximum velocity permissible for all systems using fairly dry steam from 25 inches of vacuum to 15 pounds gauge pressure should be that which would require not more than one ounce difference in pressure for one hundred feet run in straight pipe to maintain it. It is believed that this maximum velocity would give very good results for all plants with reasonably short runs, and as the length increased the individual judgment of the engineer must be used to keep the total drop in pressure within the amount desired and available.

The fact is of course recognized that there are some conditions and circumstances which would render it advisable to use a lower velocity, such as an unusual number of elbows, but it should be applicable as a maximum velocity to all ordinary cases and conditions.

If it is conceded that a standard of steam main sizes would apply for all the various pressures and methods of circulation in common use and that the maximum velocity is in the vicinity of that which would give one ounce drop for 100 feet run in straight pipe, the question is narrowed down to the formula which is

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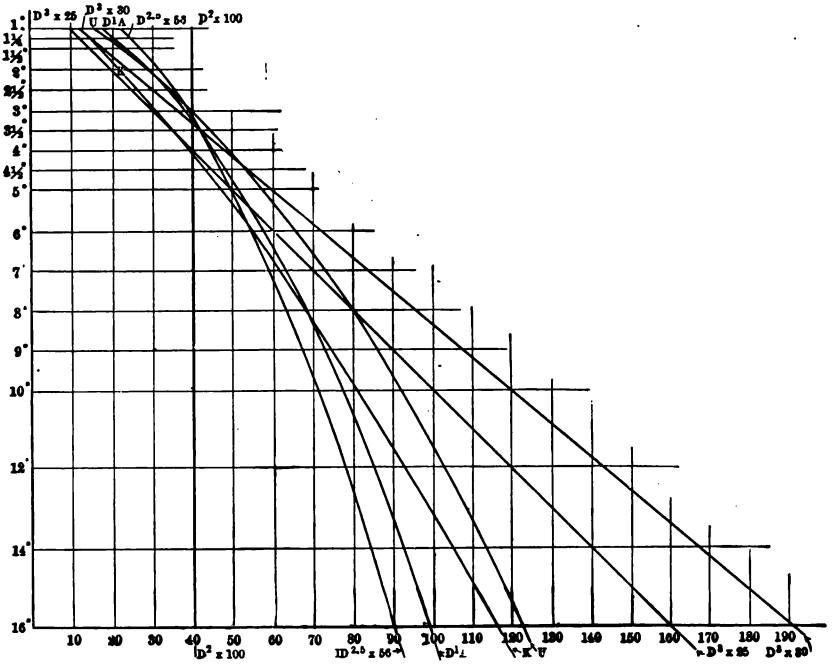
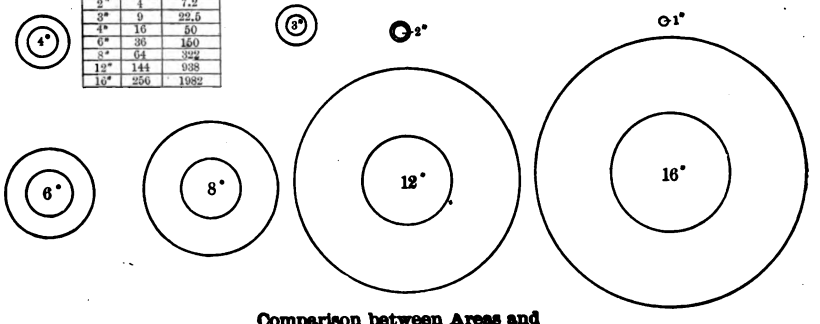



Velocity of Flow in Steam Mains—with Various Formulas—Feet per Second

| Diam. | Comp. Area | Comp Carrying Capacity |
|---|---|---|
| 1" | 1 | 1 |
| 2" | 4 | 7.2 |
| 3" | 9 | 22.5 |
| 4" | 16 | 50 |
| 6" | 36 | 160 |
| 8" | 64 | 327 |
| 12" | 144 | 938 |
| 16" | 256 | 1982 |




Comparison between Areas and Comparative Carrying Capacities of Pipes

preferable by reason of correctness and convenience for constructing a table for use in determining steam main sizes.

The formulas in common use have certainly run to extremes, as they range all the way from the very old and familiar one of $R = D^2 \times 100$ to $R = D^3 \times 25$. In these and the following formulas $R$ is direct radiating surface and $D$ is diameter in inches. With neither of these has the resulting drop in pressure been

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given, though F. R. Still has recently given the formula $R = D^3 \times 30$, and stated that this gave a drop of one ounce to 100 feet run in sizes up to 8″, above which the formula was not to be relied upon.

The formula $R = D^2 \times 100$ was seldom used or considered correct below 2″ or above 6″. Pipes below 2″ were called radiator connections and came under another rule, and plants at that time seldom ran above 6″. One of the chief objects of a formula should, however, be the possibility of extending construction to larger plants by its help, and one good test for the correctness of a formula is to figure it to somewhat of an extreme.

It is probable that the average drop in both of the formulas cited, if taken in the sizes stated, would be very nearly one ounce to the 100 feet run; but there is absolutely no good authority for either formula, as they are both more in the nature of empirical rules or rules of thumb.

The first one would make the proportionate carrying capacity of pipes vary as the square of their diameters or directly as their areas. This we know would not be correct unless they were absolutely without friction. The second one would make the capacity vary directly as the cube of the diameter, which would be directly in proportion to their areas multiplied by the proportion between area and circumference. In other words, directly as the proportion between friction surface and area.

The basis, however, of all generally accepted formulas of flow has been that the friction varied about as the square root of the friction surface in proportion to area, and this has come to be called, when referring to hydraulic formulas, the mean hydraulic radius. It is usually expressed $\sqrt{\frac{A}{C}}$ or $\sqrt{r}$. The comparative carrying capacity of pipes based on this is therefore $A\sqrt{r}$, and this is of the same proportionate value as the square root of the fifth power of the diameter or the diameter raised to the two and five-tenths power. Thus we have $D^{2.5} \div 2.546 = A\sqrt{r}$.

Unwin's formula, which has been adopted by Babcock, and as applied to steam has come to be known as the Babcock formula, makes the comparative carrying capacity of pipes vary as $D^{2.5} \times \sqrt{\frac{D}{D+3.6}}$, which in the sizes from 1 to 16″

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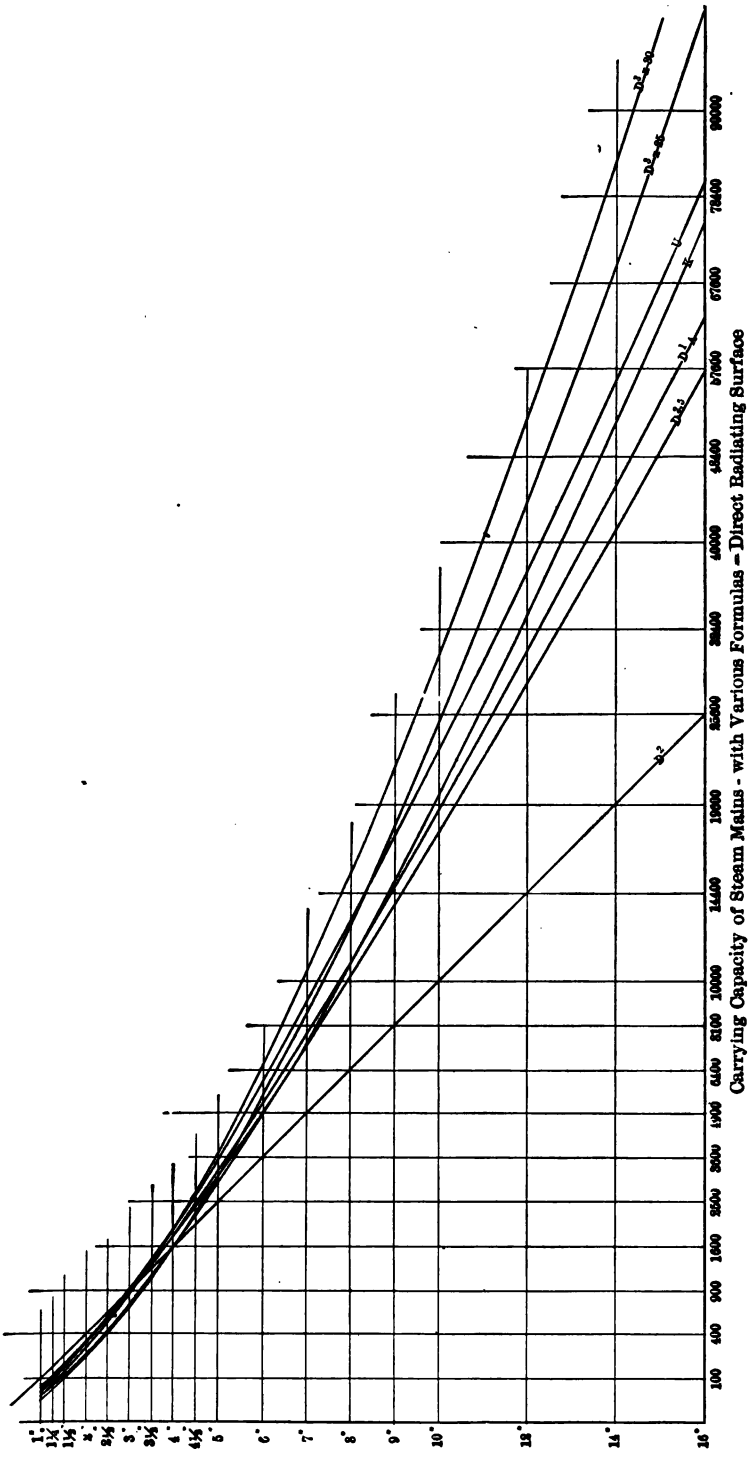


Carrying Capacity of Steam Mains - with Various Formulas - Direct Radiating Surface

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is substantially equal to $D^{2.75}$. The Darcy formula in like comparison becomes $D^{2.5} \times \sqrt{\frac{D}{D+1}}$, or $D^{2.625}$.

The changing of the formulas for the flow of water to apply to the flow of steam may be made on the general assumption that the friction and consequent velocity is proportional to the square root of the density of the fluid. This may be held to be substantially correct as between steam and water, at least in smooth pipes. For rough pipes water is no doubt affected differently from steam, due to its comparative incompressibility.

If this proportion is correct for the flow of all other fluids in comparison with water it might be advisable to use a hydraulic formula or table of flow and convert the result into that for air, gas or steam, by using the factor of the square root of the comparative density.

The result produced by a hydraulic formula may be changed into that for steam at atmospheric pressure by multiplying the velocity by 40 or dividing the weight delivered by the same factor. In like manner the factor for air at 100° is 30.

The formulas before mentioned, as well as the very widely known and much used Kutter formula, figured for smooth pipes, have been changed in this manner and made to apply to direct radiating surface. This gives in comparison with the older formulas before mentioned:

$R = D^2 \times 100$. Not figured for drop.
$R = D^{2.5} \times 56$. Weisbach. One ounce drop.
$R = D^{2.5} \times 64 \sqrt{\frac{D}{D+1}}$ or
$R = D^{2.625} \times 45$. Darcy. One ounce drop.
$R = D^{2.5} \times 87 \sqrt{\frac{D}{D+3.6}}$ or
$R = D^{2.75} \times 40$. Unwin. One ounce drop.
$R = D^{2.875} \times 30$. Kutter One ounce drop.
$R = D^3 \times 25$. Blackmore. Not figured for drop.
$R = D^3 \times 30$. Still. One ounce drop.

The authority, if any, for the drop as given by Still is not known.

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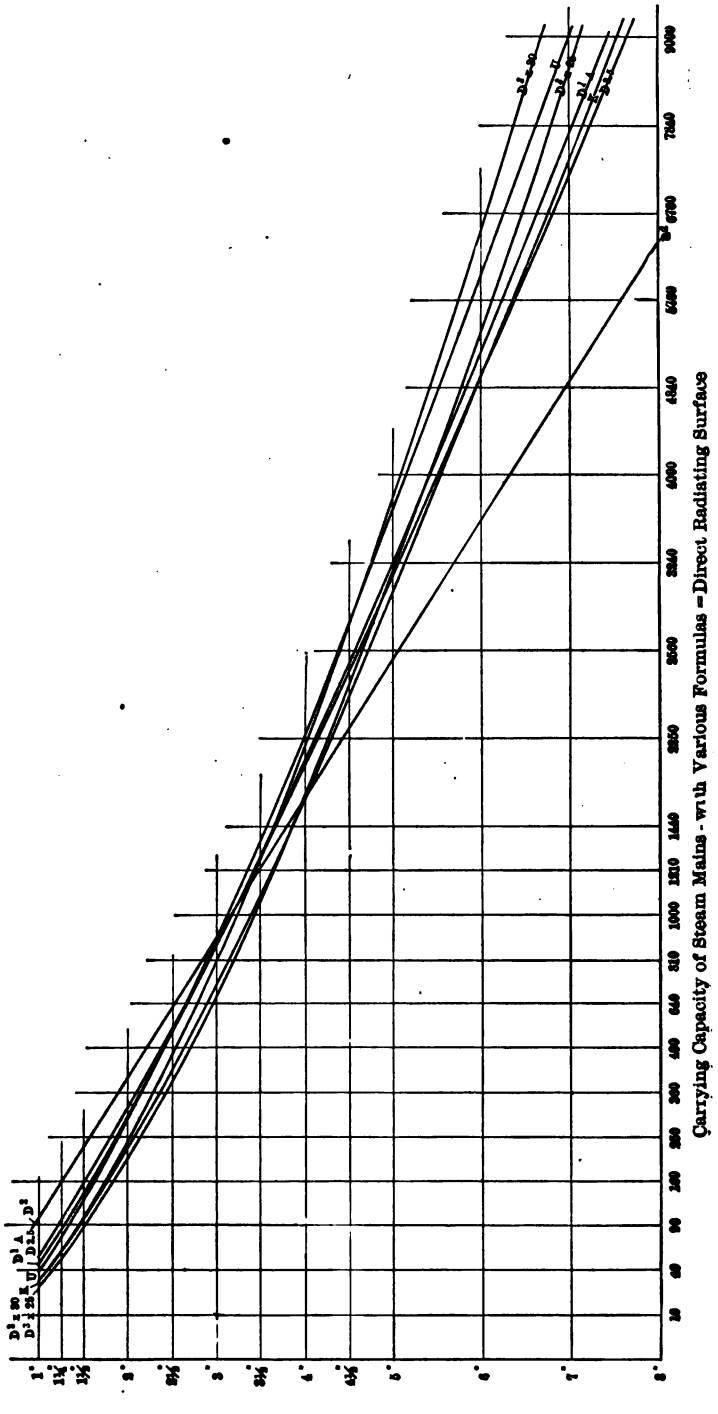

Carrying Capacity of Steam Mains - with Various Formulas = Direct Radiating Surface

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The comparative results of these formulas is given in the tables and diagrams for both velocity and quantity.

CARRYING CAPACITY OF STEAM MAINS=VARIOUS FORMULAS.

| | $D^2 \times 100$. | $D^{2.6} \times 56$. | Darcy. | Unwin. | Kutter. | $D^2 \times 25$. | $D^2 \times 30$. |
|---|---|---|---|---|---|---|---|
| 1 " | 100 | 56 | 45 | 40 | 30 | 25 | 30 |
| 1¼" | 156 | 98 | 83 | 75 | 58 | 49 | 58 |
| 1½" | 225 | 154 | 136 | 126 | 98 | 84 | 101 |
| 2 " | 400 | 317 | 294 | 286 | 218 | 200 | 240 |
| 2½" | 625 | 543 | 532 | 535 | 410 | 390 | 468 |
| 3 " | 900 | 872 | 861 | 890 | 705 | 675 | 810 |
| 3½" | 1,225 | 1,282 | 1,269 | 1,360 | 1,082 | 1,072 | 1,284 |
| 4 " | 1,600 | 1,808 | 1,824 | 1,950 | 1,592 | 1,600 | 1,020 |
| 4½ " | 2,025 | 2,424 | 2,460 | 2,747 | 2,216 | 2,278 | 2,733 |
| 5 " | 2,500 | 3,130 | 3,250 | 3,600 | 2,963 | 3,175 | 3,750 |
| 6 " | 3,600 | 4,944 | 5,203 | 5,900 | 4,917 | 5,400 | 6,480 |
| 7 " | 4,900 | 7,194 | 7,628 | 9,040 | 7,435 | 8,575 | 10,290 |
| 8 " | 6,400 | 10,160 | 10,876 | 12,700 | 10,828 | 12,800 | 15,360 |
| 9 " | 8,100 | 13,730 | 14,700 | 17,600 | 15,126 | 18,225 | 21,870 |
| 10 " | 10,000 | 17,700 | 19,195 | 22,900 | 20,008 | 25,000 | 30,000 |
| 12 " | 14,400 | 28,031 | 30,573 | 37,000 | 33,437 | 43,200 | 51,840 |
| 14 " | 19,600 | 41,153 | 45,485 | 55,300 | 51,135 | 68,600 | 82,320 |
| 16 " | 25,600 | 57,494 | 63,282 | 78,300 | 74,285 | 102,400 | 122,880 |

VELOCITY OF FLOW IN STEAM MAINS=VARIOUS FORMULAS.

| | $D^2 \times 100$. | $D^{2.6} \times 56$. | Darcy. | Unwin. | Kutter. | $D^2 \times 25$. | $D^2 \times 30$. |
|---|---|---|---|---|---|---|---|
| 1 " | 40 | 22.6 | 18.1 | 15.8 | 12. | 10. | 12. |
| 1¼" | 40 | 25.2 | 21.4 | 18.5 | 14.8 | 12.5 | 15. |
| 1½" | 40 | 27.6 | 24.3 | 22.5 | 17.5 | 15. | 18. |
| 2 " | 40 | 31.9 | 29.4 | 24.2 | 21.8 | 20. | 24. |
| 2½" | 40 | 35.7 | 35. | 34.5 | 27. | 25. | 30. |
| 3 " | 40 | 39.1 | 38.6 | 40. | 31.6 | 30. | 36. |
| 3½" | 40 | 42.2 | 41.7 | 43.4 | 35.6. | 35. | 42. |
| 4 " | 40 | 45.2 | 45.6 | 49. | 39.8 | 40. | 48. |
| 4½" | 40 | 47.9 | 48.6 | 54.8 | 43.8 | 45. | 54. |
| 5 " | 40 | 50.5 | 52.4 | 58. | 47.8 | 50. | 60. |
| 6 " | 40 | 55.3 | 58.2 | 66. | 55. | 60. | 72. |
| 7 " | 40 | 59.7 | 63.3 | 74.3 | 61.7 | 70. | 84. |
| 8 " | 40 | 63.9 | 68.4 | 80. | 68.1 | 80. | 96. |
| 9 " | 40 | 67.8 | 72.6 | 87.4 | 74.7 | 90. | 108. |
| 10 " | 40 | 71.4 | 77.4 | 92. | 81. | 100. | 120. |
| 12 " | 40 | 78.3 | 85.4 | 103. | 93.4 | 120. | 144. |
| 14 " | 40 | 84.5 | 93.4 | 113. | 105. | 140. | 168. |
| 16 " | 40 | 90.4 | 99.5 | 123. | 116.8 | 160. | 192. |

Many other formulas for the flow of water have exponents of the diameter very similar to these, such as Hagen $D^{2.58}$, Thrupp $D^{2.61}$, Vallot $D^{2.66}$.

A formula for the flow of air, by Frank Richards, giving comparative results substantially the same as the Unwin, has been very widely used. The Unwin formula for steam has been used by Carpenter and Wolf and the Darcy formula by the Armour Institute of Technology for figuring steam main sizes.

There is one other subject that might profitably be taken up in relation to the sizes of steam mains. The relation between the velocity of the flow of the steam and the possibility of proper drainage of condensation has not received the attention that it

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should in order to obtain a proper proportioning of steam main sizes.

In one-pipe steam radiator connections it has been observed that the condensation will not run in opposition to the steam flow if the velocity is over ten to fifteen feet per second in pipes from 1¼ to 2 inches in diameter. Drop feed steam risers and mains in which the condensation runs with the steam are much better practice than up feed risers and counter flow mains; not so much from the fact that the water helps the steam flow as that the steam helps the water to the drip point.

In up feed steam risers there is a limit to the velocity which will allow the condensation to flow back down the pipe. If this velocity is exceeded the friction of the steam on the water becomes greater than the force of gravity acting on the water and the condensation is carried upward.

In the case of drops of water not in contact with the interior of the pipe this formula becomes substantially $V = 100\sqrt{D}$. In which $V$ is velocity in feet per second and $D$ is diameter in inches. This gives a velocity of 50 feet per second for drops ¼ of an inch in diameter, which is practically the size of drops falling from ordinary surfaces in still air. Where there is a current of air or steam or where the contact point is quite small the drops will be smaller. If they are $\frac{1}{16}$ of an inch in diameter the velocity becomes 25 feet per second.

There do not seem to be any data available as a guide for figuring the velocity which would carry up water that was in contact with the side of the pipe, but it would probably be very much the same as that for drops not in contact with the side.

It is very evident in many cases that the greater part of the water that is removed by the drip of the exhaust head is that which is carried up by the steam and that a much less amount would be present were the velocity sufficiently low to allow it to drip back against the flow of the steam.

It has been noted and commented upon that the water of condensation in a horizontal steam pipe does not lie at all uniformly along the bottom of the pipe, but that it clings to the sides as well. This is probably caused to a great extent by too high a velocity.

It would seem as if a series of experiments on velocity and drainage of condensation in steam mains would be of great value to heating engineers.

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The following tables of the losses of pressure in steam mains and of the equalization of pipes were compiled by the writer in 1904 and they are added in order to make the present discussion more complete.

An illustration is also given of the relation between actual areas and comparative carrying capacities of pipes.

EQUALIZATION OF PIPES. UNWIN FORMULA.

| | 1" | 1¼" | 1½" | 2" | 2½" | 3" | 3½" | 4" | 4½" | 5" | 6" | 7" | 8" | 9" | 10" | 12" | 14" | 16" |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 " | 1. | 1.9 | 3.2 | 7.2 | 13.6 | 22.5 | 34.5 | 50. | 68.7 | 91.4 | 150. | 226. | 322. | 440. | 582. | 938. | 1405. | 1982. |
| 1¼" | 1. | 1. | 1.7 | 3.8 | 7.2 | 12. | 18.2 | 26.3 | 36.2 | 48.1 | 79. | 119. | 170. | 232. | 306. | 494. | 740. | 1043. |
| 1½" | | | 1. | 2.65 | 4. | 7. | 10.8 | 15. | 21.5 | 28.6 | 47. | 73.8 | 100. | 138. | 182. | 293. | 439. | 650. |
| 2 " | | | | 1. | 1.9 | 3.12 | 4.8 | 6.94 | 9.54 | 12.7 | 20.8 | 31.4 | 44.7 | 61. | 80.8 | 130. | 195. | 275. |
| 2½" | | | | | 1. | 1.65 | 2.54 | 3.68 | 5.05 | 6.72 | 11. | 16.6 | 23.7 | 32.4 | 42.8 | 69. | 103. | 146. |
| 3 " | | | | | | 1. | 1.5 | 2.22 | 3.05 | 4.06 | 6.7 | 10. | 14.3 | 19.5 | 26. | 41.2 | 62.4 | 88. |
| 3½" | | | | | | | 1. | 1.45 | 2. | 2.65 | 4.35 | 6.55 | 9.3 | 12.8 | 16.9 | 27.2 | 40.7 | 57.4 |
| 4 " | | | | | | | | 1. | 1.37 | 1.83 | 3. | 4.52 | 6.44 | 8.8 | 11.6 | 18.7 | 28.1 | 39.6 |
| 4½" | | | | | | | | | 1. | 1.3 | 2.18 | 3.29 | 4.69 | 6.4 | 8.47 | 13.7 | 20.5 | 28.8 |
| 5 " | | | | | | | | | | 1. | 1.64 | 2.47 | 3.52 | 4.81 | 6.37 | 10.3 | 15.4 | 21.7 |
| 6 " | | | | | | | | | | | 1. | 1.5 | 2.15 | 2.93 | 3.88 | 6.25 | 9.4 | 13.2 |
| 7 " | | | | | | | | | | | | 1. | 1.3 | 1.9 | 2.6 | 4.2 | 6.2 | 8.8 |
| 8 " | | | | | | | | | | | | | 1. | 1.37 | 1.8 | 2.9 | 4.67 | 6.2 |
| 9 " | | | | | | | | | | | | | | 1. | 1.32 | 2.1 | 3.2 | 4.5 |
| 10 " | | | | | | | | | | | | | | | 1. | 1.6 | 2.4 | 3.4 |
| 12 " | | | | | | | | | | | | | | | | 1. | 1.5 | 2.1 |
| 14 " | | | | | | | | | | | | | | | | | 1. | 1.4 |
| 16 " | | | | | | | | | | | | | | | | | | 1. |

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## SIZES OF STEAM MAINS FOR DIRECT RADIATION.

Showing Loss of Pressure in ounces for 100 ft. Run.

Three-tenths Pound Condensation per Square Foot per Hour.

| | Nominal Sizes of Pipe Used. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10′ | | 20′ | | 30′ | | 40′ | | 50′ | | 60′ | |
| | oz. | Sq.ft. | oz. | Sq.ft. | oz. | Sq.ft. | oz. | Sq. ft. | oz. | Sq. ft. | oz. | Sq. ft. |
| 1 ″ | .4 | 25 | 1.6 | 49 | 3.6 | 74 | 6. | 100 | 10. | 124 | 14.4 | 148 |
| 1¼″ | .29 | 39 | 1.16 | 77 | 2.61 | 116 | 4.64 | 155 | 7.25 | 194 | 10.44 | 232 |
| 1½″ | .2 | 56 | .8 | 112 | 1.80 | 168 | 3.2 | 224 | 5. | 280 | 7.2 | 336 |
| 2 ″ | ... | .. | .48 | 200 | 1.08 | 300 | 1.92 | 400 | 3. | 500 | 4.32 | 600 |
| 2½″ | ... | .. | .... | ... | .75 | 465 | 1.34 | 620 | 2.1 | 775 | 3.02 | 930 |
| 3 ″ | ... | .. | .... | ... | .56 | 669 | 1. | 892 | 1.56 | 1,115 | 2.25 | 1,338 |
| 3½″ | ... | .. | .... | ... | .... | ... | .85 | 1,216 | 1.33 | 1,520 | 1.9 | 1,824 |
| 4 ″ | ... | .. | .... | ... | .... | ... | .66 | 1,600 | 1.04 | 2,000 | 1.5 | 2,400 |
| 4½″ | ... | .. | .... | ... | .... | ... | .53 | 2,005 | .83 | 2,506 | 1.2 | 3,007 |
| 5 ″ | ... | .. | .... | ... | .... | ... | .48 | 2,480 | .75 | 3,100 | 1.08 | 3,720 |
| 6 ″ | ... | .. | .... | ... | .... | ... | .... | ..... | .57 | 4,470 | .82 | 5,364 |
| 7 ″ | ... | .. | .... | ... | .... | ... | .... | ..... | .45 | 6,083 | .652 | 7,300 |
| 8 ″ | ... | .. | .... | ... | .... | ... | .... | ..... | ..... | ..... | .56 | 9,540 |
| 9 ″ | ... | .. | .... | ... | .... | ... | .... | ..... | ..... | ..... | ..... | ..... |
| 10 ″ | ... | .. | .... | ... | .... | ... | .... | ..... | ..... | ..... | ..... | ..... |
| 12 ″ | ... | .. | .... | ... | .... | ... | .... | ..... | ..... | ..... | ..... | ..... |
| 14 ″ | ... | .. | .... | ... | .... | ... | .... | ..... | ..... | ..... | ..... | ..... |
| 16 ″ | ... | .. | .... | ... | .... | ... | .... | ..... | ..... | ..... | ..... | ..... |

| | Nominal Sizes of Pipe Used. | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 70′ | | 80′ | | 90′ | | 100′ | | 110′ | |
| | oz. | Sq. ft. | oz. | Sq. ft. | oz. | Sq. ft. | oz. | Sq. ft. | oz. | Sq. ft. |
| 1 ″ | 19.6 | 174 | 25.6 | 198 | 32.4 | 224 | 40. | 248 | .... | ..... |
| 1¼″ | 14.21 | 271 | 18.56 | 310 | 23.5 | 350 | 29. | 388 | .... | ..... |
| 1½″ | 9.8 | 392 | 12.8 | 448 | 16.2 | 504 | 20. | 560 | .... | ..... |
| 2 ″ | 5.88 | 700 | 7.68 | 800 | 9.72 | 900 | 12. | 1,000 | .... | ..... |
| 2½″ | 4.1 | 1,085 | 5.37 | 1,240 | 6.8 | 1,395 | 8.4 | 1,550 | .... | ..... |
| 3 ″ | 3.06 | 1,561 | 4. | 1,784 | 5.06 | 2,007 | 6.25 | 2,230 | .... | ..... |
| 3½″ | 2.6 | 2,128 | 3.4 | 2,432 | 4.3 | 2,736 | 5.31 | 3,040 | .... | ..... |
| 4 ″ | 2.04 | 2,800 | 2.66 | 3,200 | 3.37 | 3,600 | 4.16 | 4,000 | .... | ..... |
| 4½″ | 1.63 | 3,508 | 2.13 | 4,009 | 2.69 | 4,510 | 3.33 | 5,012 | .... | ..... |
| 5 ″ | 1.37 | 4,340 | 1.92 | 4,960 | 2.43 | 5,580 | 3. | 6,200 | .... | ..... |
| 6 ″ | 1.12 | 6,258 | 1.47 | 7,152 | 1.86 | 8,046 | 2.3 | 8,940 | .... | ..... |
| 7 ″ | .887 | 8,516 | 1.16 | 9,733 | 1.46 | 10,950 | 1.81 | 12,167 | .... | ..... |
| 8 ″ | .76 | 11,130 | 1. | 12,720 | 1.26 | 14,310 | 1.56 | 15,900 | 1.89 | 17,490 |
| 9 ″ | .637 | 14,095 | .83 | 16,109 | 1.06 | 18,123 | 1.3 | 20,137 | 1.58 | 22,150 |
| 10 ″ | .57 | 17,360 | .75 | 19,840 | .95 | 22,320 | 1.18 | 24,800 | 1.43 | 27,280 |
| 12 ″ | ..... | ..... | .60 | 28,640 | .76 | 32,220 | .94 | 35,800 | 1.14 | 39,380 |
| 14 ″ | ..... | ..... | .... | ..... | .63 | 43,830 | .78 | 48,700 | .95 | 53,570 |
| 16 ″ | ..... | ..... | .... | ..... | .53 | 57,240 | .66 | 63,600 | .80 | 69,960 |

| | Nominal Sizes of Pipe Used. | | | | 100 ft. Run. 1 oz. Drop. | | Comparative Carrying Capacity of Pipes. | |
|---|---|---|---|---|---|---|---|---|
| | 120′ | | 130′ | | | | | |
| | oz. | Sq. ft. | oz. | Sq. ft. | Vel. | Sq. ft. | | |
| 1 ″ | .... | ..... | .... | ..... | 15.8 | 40 | 1. | ... 1 ″ |
| 1¼″ | .... | ..... | .... | ..... | 18.5 | 75 | 1.9 | ... 1¼″ |
| 1½″ | .... | ..... | .... | ..... | 22.5 | 126 | 3.2 | ... 1½″ |
| 2 ″ | .... | ..... | .... | ..... | 29. | 286 | 7.2 | ... 2 ″ |
| 2½″ | .... | ..... | .... | ..... | 34.5 | 535 | 13.5 | ... 2½″ |
| 3 ″ | .... | ..... | .... | ..... | 40. | 890 | 22.5 | ... 3 ″ |
| 3½″ | .... | ..... | .... | ..... | 43.4 | 1,360 | 34.4 | ... 3½″ |
| 4 ″ | .... | ..... | .... | ..... | 49. | 1,950 | 50. | ... 4 ″ |
| 4½″ | .... | ..... | .... | ..... | 54.8 | 2,747 | 68.6 | ... 4½″ |
| 5 ″ | .... | ..... | .... | ..... | 58. | 3,600 | 91.3 | ... 5 ″ |
| 6 ″ | .... | ..... | .... | ..... | 66. | 5,900 | 150. | ... 6 ″ |
| 7 ″ | .... | ..... | .... | ..... | 74.3 | 9,040 | 226. | ... 7 ″ |
| 8 ″ | 2.25 | 19,080 | .... | ..... | 80. | 12,700 | 322. | ... 8 ″ |
| 9 ″ | 1.87 | 24,157 | 2.2 | 26,170 | 87.4 | 17,600 | 440. | ... 9 ″ |
| 10 ″ | 1.7 | 29,760 | 2. | 32,240 | 92. | 22,900 | 582. | ... 10 ″ |
| 12 ″ | 1.36 | 42,960 | 1.59 | 46,540 | 103. | 37,000 | 938. | ... 12 ″ |
| 14 ″ | 1.13 | 58,440 | 1.32 | 63,310 | 113. | 55,300 | 1,403. | ... 14 ″ |
| 16 ″ | .95 | 76,320 | 1.12 | 82,680 | 123. | 78,300 | 1,982. | ... 16 ″ |

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## CLXXI.

# THE CARRYING CAPACITY OF PIPES IN LOW PRESSURE STEAM HEATING.

BY WILLIAM KENT.

(Member of the Society.)

The old tables for proportioning steam pipes to the amount of radiating surface supplied by them were based upon experience with small installations, where lines were short and radiating surface not extensive. They gave satisfaction generally, and while often they provided for larger sizes of pipe than were actually necessary, the saving of cost which might have been made by using smaller sizes was not enough to justify taking the risk of such smaller sizes not giving satisfaction.

In any case, a pipe should be proportioned for the worst set of conditions that are likely to be met. In the ordinary small installation the probability of frequent bad conditions is very great. Among them are occasional excessive steam demand in certain rooms, due to their being cold or to opening of windows; air bound radiators; clogged returns; obstruction to flow of steam due to right angle bends and globe valves; low steam pressure due to excessive demand, to poor draft, to poor coal, or to fire poorly attended; insufficient supply of steam to some rooms, owing to insufficient or ineffective radiating surface, or to faulty pipe arrangements, causing short circuiting or easier flow of steam to some rooms than to others.

In modern practice many of these difficulties are greatly lessened. The wider experience of heating engineers and contractors has led generally to the provision of ample grate surface and heating surface in boilers, so that there is little probability of a deficient steam supply; and steam and return pipes are properly laid so there is less liability of obstructions to flow of steam or water. Installations are in general much larger than formerly,

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so that it is more important from the standpoint of first cost not to use pipes which are larger than necessary. The time seems to have arrived when steam piping should be proportioned on a more logical basis than has been the custom heretofore. The following tables are offered as a contribution to this question. They are based on an assumed drop of 1 pound pressure per 1,000 feet of length, not because that is the drop which should always be used—in fact the writer believes that in large installations a far greater drop is permissible—but because it gives a basis upon which the flow for any other drop may be calculated, merely by multiplying the figures in the tables by the square root of the assigned drop. The formula from which the tables are calculated is the well known one $W = c\sqrt{\frac{w(p_1 - p_2)d^5}{L}}$ in which W = weight of steam per minute; $w$ = weight of steam in pounds per cubic foot, at the entering pressure, $p_1$; $p_2$ the pressure at the end of the pipe; $d$ the actual diameter of standard wrought iron pipe in inches, and $L$ the length in feet. The coefficients $c$ are derived from Darcy's experiments on flow of water in pipes, and are believed to be as accurate as any that have been derived from the very few recorded experiments on steam. Should future experiments give more accurate figures the tables can be modified to correspond.

FLOW OF STEAM AT LOW PRESSURES IN POUNDS PER MINUTE FOR A UNIFORM DROP AT THE RATE OF ONE POUND PER 1,000 FEET LENGTH OF STRAIGHT PIPE.

| Nominal diam. of Pipe, in. | Steam Pressures, by Gauge, at Entrance of Pipe. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0.3 | 1.3 | 2.3 | 3.3 | 4.3 | 5.3 | 6.3 | 8.3 | 10.3 |
| | Flow of steam, pounds per minute. | | | | | | | | |
| ½ | .070 | .072 | .074 | .076 | .078 | .080 | .082 | .085 | .089 |
| ¾ | .161 | 1.66 | .171 | .375 | .180 | .184 | .188 | .197 | .205 |
| 1 | .317 | .326 | .336 | .345 | .354 | .362 | .371 | .387 | .403 |
| 1¼ | .668 | .688 | .708 | .728 | .746 | .765 | .782 | .817 | .849 |
| 1½ | 1.023 | 1.054 | 1.085 | 1.114 | 1.143 | 1.171 | 1.198 | 1.250 | 1.300 |
| 2 | 2.013 | 2.075 | 2.136 | 2.191 | 2.250 | 2.305 | 2.358 | 2.462 | 2.560 |
| 2½ | 3.261 | 3.363 | 3.459 | 3.553 | 3.645 | 3.734 | 3.820 | 3.987 | 4.147 |
| 3 | 5.758 | 5.935 | 6.108 | 6.274 | 6.435 | 6.592 | 6.745 | 7.040 | 7.321 |
| 3½ | 8.421 | 8.680 | 8.932 | 9.175 | 9.411 | 9.642 | 9.864 | 10.30 | 10.71 |
| 4 | 11.69 | 12.05 | 12.40 | 12.74 | 13.07 | 13.39 | 13.70 | 14.29 | 14.86 |
| 4½ | 15.64 | 16.13 | 16.59 | 17.05 | 17.48 | 17.91 | 18.33 | 19.13 | 19.89 |
| 5 | 20.87 | 21.51 | 22.14 | 22.74 | 23.32 | 23.89 | 24.45 | 25.52 | 26.54 |
| 6 | 33.52 | 34.56 | 35.56 | 36.53 | 37.46 | 38.38 | 39.27 | 40.99 | 42.62 |
| 7 | 48.94 | 50.45 | 51.91 | 53.32 | 54.69 | 56.03 | 57.33 | 59.83 | 62.22 |
| 8 | 68.04 | 70.14 | 72.18 | 74.14 | 76.04 | 77.90 | 79.71 | 83.19 | 86.51 |
| 9 | 91.03 | 93.83 | 96.56 | 99.18 | 101.7 | 104.2 | 106.6 | 111.3 | 115.7 |
| 10 | 121.9 | 125.6 | 129.3 | 132.8 | 136.2 | 139.5 | 142.7 | 149.0 | 154.9 |
| 12 | 192.5 | 198.6 | 204.4 | 209.9 | 215.3 | 220.6 | 225.7 | 235.6 | 145.0 |

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Formula $W = c\sqrt{\frac{w(p_1 - p_2)d^5}{L}}$

W = weight of steam, lbs. per minute; c = constant; w = weight of steam at pressure $p_1$ in lbs. per cu. ft.; $p_1 - p_2$ = drop in pressure, lbs. per sq. in.; d = actual inside diameter of pipe, inches; L = length in feet.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Nominal diam. of pipe..... | ½ | ¾ | 1 | 1¼ | 1½ | 2 | 2½ | 3 | 3½ |
| Value of c..... | 36.8 | 42 | 45.3 | 48 | 50 | 52.7 | 54.8 | 56.2 | 57.1 |
| Nominal diam. of pipe..... | 4 | 4½ | 5 | 6 | 7 | 8 | 9 | 10 | 12 |
| Value of c..... | 57.8 | 58.3 | 58.7 | 59.5 | 60.2 | 60.8 | 61.3 | 61.7 | 62.1 |

For any other drop of pressure per 1,000 feet per length, multiply the figures in the table by the square root of that drop.

**FLOW OF STEAM AT LOW PRESSURES IN POUNDS PER HOUR FOR A UNIFORM DROP AT THE RATE OF ONE POUND PER 1,000 FEET LENGTH OF STRAIGHT PIPE.**

| Nominal diam. of Pipe. | Steam Pressures, by Gauge, at entrance of Pipe. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0.3 | 1.3 | 2.3 | 3.3 | 4.3 | 5.3 | 6.3 | 8.3 | 10.3 |
| | Flow of steam, pounds per hour. | | | | | | | | |
| ¼ | 4.2 | 4.3 | 4.4 | 4.6 | 4.7 | 4.8 | 4.9 | 5.1 | 5.3 |
| ¾ | 9.7 | 10.0 | 10.3 | 10.5 | 10.8 | 11.0 | 11.3 | 11.8 | 12.3 |
| 1 | 19.0 | 19.6 | 20.2 | 20.7 | 21.2 | 21.7 | 22.3 | 23.2 | 24.2 |
| 1¼ | 40.1 | 41.3 | 42.5 | 43.7 | 44.8 | 45.9 | 46.9 | 49.0 | 50.9 |
| 1½ | 61.4 | 63.2 | 65.1 | 66.8 | 68.6 | 70.3 | 71.9 | 75.0 | 78.0 |
| 2 | 120.8 | 124.5 | 128.2 | 131.6 | 135.0 | 138.3 | 141.5 | 147.7 | 153.6 |
| 2½ | 195.7 | 201.8 | 207.5 | 213.2 | 218.7 | 224.0 | 229.2 | 239.2 | 248.8 |
| 3 | 345.5 | 356.1 | 366.5 | 376.4 | 386.1 | 395.5 | 404.7 | 422.4 | 439.3 |
| 3½ | 505.3 | 520.8 | 535.9 | 550.5 | 564.7 | 578.5 | 591.8 | 618.0 | 642.6 |
| 4 | 701.4 | 723.0 | 744.0 | 764.4 | 784.2 | 803.4 | 822.0 | 857.4 | 891.6 |
| 4½ | 938.7 | 967.6 | 995.8 | 1023. | 1049. | 1075. | 1100. | 1148. | 1193. |
| 5 | 1252. | 1291. | 1328. | 1364. | 1399. | 1433. | 1467. | 1531. | 1592. |
| 6 | 2011. | 2074. | 2134. | 2192. | 2248. | 2303. | 2356. | 2459. | 2557. |
| 7 | 2936. | 3027. | 3115. | 3199. | 3281. | 3362. | 3440. | 3590. | 3733. |
| 8 | 4082. | 4208. | 4331. | 4448. | 4564. | 4674. | 4783. | 4991. | 5191. |
| 9 | 5462. | 3630. | 5794. | 5951. | 6102. | 6252. | 6396. | 6678. | 6942. |
| 10 | 7314. | 7536. | 7758. | 7968. | 8172. | 8370. | 8562. | 8940. | 9294 |
| 12 | 11550. | 11916. | 12264. | 12594. | 12918. | 13236. | 13542. | 14136. | 14700. |

**FIGURES USED IN CALCULATION OF RADIATING SURFACE.**

P = Pressure by gauge, lbs. per sq. in.

| 0. | 0.3 | 1.3 | 2.3 | 3.3 | 4.3 | 5.3 | 6.3 | 8.3 | 10.3 |
|---|---|---|---|---|---|---|---|---|---|
| L = latent heat of evaporation, B.T.U. per lb. | | | | | | | | | |
| 965.7 | 965.0 | 962.6 | 960.4 | 958.3 | 956.3 | 954.4 | 952.6 | 949.1 | 945.8 |
| Temperature Fahrenheit, $T_2$. | | | | | | | | | |
| 212. | 213. | 216.3 | 219.4 | 222.4 | 225.2 | 227.9 | 230.5 | 235.4 | 240.0 |
| $T_1 = T_2 - 70°$, difference of temperature. | | | | | | | | | |
| 142. | 143. | 146.3 | 149.4 | 152.4 | 155.2 | 157.9 | 160.5 | 165.4 | 170.0 |
| $H_1 = T_1 \times 1.8$ = heat transmission per sq. ft. radiating surface, B.T.U. per hour. | | | | | | | | | |
| 255.6 | 257.4 | 263.3 | 268.9 | 274.3 | 279.2 | 284.2 | 288.9 | 297.7 | 306.0 |
| $\frac{H_1}{L}$ = steam condensed per sq. ft. radiating surface, lbs. per hour. | | | | | | | | | |
| 0.2647 | .267 | .274 | 280 | .286 | .292 | .298 | .303 | .314 | .324 |
| Reciprocal of above = radiating surface per lb. of steam condensed per hour. | | | | | | | | | |
| 3.78 | 3.75 | 3.65 | 3.57 | 3.50 | 3.42 | 3.36 | 3.30 | 3.18 | 3.09 |

The last three lines of figures are based on the empirical constant 1.8 for the average British thermal units transmitted per square foot of radiating surface per hour per degree of difference

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of temperature. This figure is approximately correct for several forms of both cast-iron radiators and pipe coils, not over 30 inches high and not over two pipes in width.

RADIATING SURFACE SUPPLIED BY DIFFERENT SIZES OF PIPE.

On basis of steam in pipe at 0.3 and 10.3 pounds gauge pressure, temperature of room 70°, heat transmitted per square foot radiating surface 255.6 British thermal units per hour, and drop of pressure in pipe at the rate of 1 pound per 1,000 feet length; = pounds of steam per hour in preceding table, 1st column, × 3.75, and last column × 3.09.

| SIZE OF PIPE (NOMINAL) IN. | RADIATING SURFACE, SQ. FT. PRESSURE. 0.3 LB. | 10.3 LBS. | WOLFF'S TABLE FOR COMPARISON. (a) PRESSURE. 2 LBS. | 5 LBS. |
|---|---|---|---|---|
| ½ | 16 | 16 | ..... | ..... |
| ¾ | 36 | 38 | ..... | ..... |
| 1 | 71 | 75 | 36 | 60 |
| 1¼ | 150 | 157 | 72 | 120 |
| 1½ | 230 | 241 | 120 | 200 |
| 2 | 453 | 475 | 280 | 480 |
| 2½ | 734 | 769 | 528 | 880 |
| 3 | 1,296 | 1,357 | 900 | 1,500 |
| 3½ | 1,895 | 1,986 | 1,320 | 2,200 |
| 4 | 2,630 | 2,755 | 1,920 | 3,200 |
| 4½ | 3,520 | 3,686 | 2,760 | 4,600 |
| 5 | 4,695 | 4,919 | 3,720 | 6,200 |
| 6 | 7,541 | 7,901 | 6,000 | 10,000 |
| 7 | 11,010 | 11,535 | 9,000 | 15,000 |
| 8 | 15,307 | 16,040 | 12,800 | 21,600 |
| 9 | 20,482 | 21,451 | 17,800 | 30,000 |
| 10 | 27,427 | 28,718 | 23,200 | 39,000 |
| 12 | 43,312 | 45,423 | 37,000 | 62,000 |

(a)—Carpenter's Heating and Ventilating, p. 258.

## GENERAL RULE FOR PROPORTIONING STEAM PIPES TO STEAM RADIATING SURFACE.

Given the number of square feet of radiating surface, the coefficient of transmission of that surface in British thermal units per hour (generally taken at 1.8, but may be greater or less than this according to the form of radiator), and the difference of temperature between the steam in the radiator and the temperature of the room ($T_1 - T_2$). Multiply the coefficient by the difference of temperature and by the number of square feet of radiating surface. This gives the total emission of heat in British thermal units per hour. Divide this by the latent heat, $L$, corresponding to the steam pressure in the radiator. This will give the number of pounds of steam condensed per hour and the number of pounds of steam that have to be conveyed through the pipe. Then from the table of flow in pounds per hour select the pipe which will carry that number of pounds with a drop of one pound per 1,000 feet of length. For any other assumed drop, divide the number of pounds of steam to be carried by the square root of the drop

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in pounds per 1,000 feet and then select from the table the size of pipe corresponding to the quotient.

Example: Required the size of pipe to supply 10,000 square feet of radiating surface when the entering pressure in the steam pipe is 5.3 pounds by gauge and is reduced by throttling at the entrance of the radiator to 1.3 pounds, assuming a drop at the rate of four pounds for each 1,000 feet of length of pipe, the coefficient of transmission of the radiator to be 1.8, and the temperature in the room 70°.

Solution: Difference of temperature, $216.3 - 70 = 146.3 \times 1.8 = 263.3 \times 10{,}000 = 2{,}633{,}000$ British thermal units per hour.

Divide by latent heat $962.6 = 2{,}735$ pounds per hour. According to the table, at 5.3 pounds entering pressure this will be conveyed by a 7-inch pipe if the drop is only one pound per 1,000 feet, but for a drop of 4 pounds pressure, twice as much steam, 5,471 pounds per hour, would be conveyed by a 7-inch pipe.

Dividing $2{,}735$ by $2 = 1{,}368$, and this would be carried according to the table by a 5-inch pipe. The 2,735 pounds, therefore, will be carried by a 5-inch pipe with a drop of four pounds per 1,000. A 5-inch pipe is therefore the one to be selected for the 10,000 square feet of radiating surface, although according to the above table for radiating surface corresponding to given sizes of pipe it will only supply 4,695 square feet.

In all cases the judgment of the engineer must be used in the assumption of the drop to be allowed. For small distributing pipes it will generally be desirable to assume a drop of not more than one pound per 1,000 feet to insure that each single radiator shall always have an ample supply for the worst conditions, and in that case the sizes of piping given in the table up to two inches may be used; but for main pipes supplying totals of more than 500 square feet, greater drops may be allowed and calculations should be made as in the above example.

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## DISCUSSION.

Prof. William Kent (written discussion): A careful reading of Mr. Donnelly's paper shows that his principal conclusions as to standard sizes of pipes may be condensed into the following statements:

1. The maximum velocity permissible for all systems using fairly dry stream from 25 inches of vacuum to 15 pounds gauge pressure should be that which would require not more than one ounce difference in pressure for 100 feet run in a straight pipe to maintain it.

2. With this assigned difference in pressure, different formulas give the number of square feet of radiating surface which can be supplied by different sizes of pipe ranging as widely as the following: 1-inch pipe, 25 to 100 square feet; 2-inch pipe, 200 to 400 square feet; 10-inch pipe, 10,000 to 30,000 square feet.

The second statement is no doubt correct, for the formulæ of different authors show wide variation both in their constants and in their exponents, and it is not to be expected that arithmetical results computed from them for different sizes of pipes will give any close agreement.

The first statement does not appear to have any basis either in theory or pracitce. Mr. Donnelly does not submit any proofs of its correctness, but instead makes the following statements:

"There seems to be no good reason why a larger drop should be desired when a higher pressure is to be used. It is certain that the saving in the first cost would not warrant the resulting decrease in efficiency."

"As an increase in velocity is always attended by a decrease in efficiency, the same standard of sizes of steam mains is advisable with all methods of circulation."

Mr. Donnelly makes another statement to the effect that for all the various pressures and methods of circulation in pipe, the same size of pipe may be used for a given amount of radiating surface. "The amount of radiation that may be put upon pipes for a uniform drop is practically the same for reasonable differences in pressures, as will be seen by the table on page 44." The table seems to confirm this statement, by showing that with 1 ounce drop per 100 feet of length a 10-inch pipe will supply 22,000 square feet at atmospheric pressure, 22,600 feet at 16 inches

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vacuum, 21,600 square feet at 5 pounds and 21,000 pounds at 10 pounds gauge pressure, and as already shown one formula gives 10,000 square feet and another 30,000 square feet, the pressure not being stated. Mr. Wolff's table (Carpenter's Heating and Ventilation, p. 258) gives as the capacity of a 10-inch pipe, 23,300 square feet for 2 pounds and 39,000 feet for 5 pounds.

The fundamental trouble with Mr. Donnelly's method of arriving at standard sizes for pipe is that he assumes that there is a necessary relation between the size of pipe and the number of square feet of radiating surface, while the fact is that there is no such relation. The accidental result that a 10-inch pipe will supply from 21,000 to 22,600 square feet for all pressure from 10 pounds gauge down to 16 inches vacuum is based on the purely arbitrary assumption that the drop for all pressures should be one ounce per 100 for length.

The number of square feet of radiating surface for any given case should be figured from the following data: 1st, the number of heat units to be transmitted by the heating surface; 2d, the difference in temperature of the steam in the radiator and the atmosphere in the room to be heated; 3d, the coefficient of transmission, that is, the number of B. T. U. which a square foot of the surface will transmit per hour per degree of difference of temperature, which will depend on the form of the radiator and to some extent upon the temperature difference. For a given quantity of heat to be transmitted the number of square feet of radiating surface required will vary largely with the other data.

The first of these data, the number of heat units to be transmitted, is the only one of the three that enters into the calculation of the size of the pipe, and this datum has to be translated into the number of pounds of steam to be carried, by dividing the heat units by the latent heat of steam at the temperature in the radiator. Given the number of pounds of steam to be carried per hour we must then know the drop to be allowed in the pipe before we can calculate the size of the pipe. This drop has to be assumed by the engineer, for there is no standard fixed by either theory or practice on which it can be based. There seems to be no good reason why it should be taken at one ounce per 100 feet for all pressures, especially for the largest sizes of steam mains, and for pressures above the atmosphere.

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Let us make some calculations to see if we can reach a logical basis for proportioning steam mains. We start with the following figures, computed on the basis of three different pressures in the radiator:

| Pressures in the Radiator. | 10 in. Vacuum. | 0. lb. Gauge. | 10.3 lbs. |
|---|---|---|---|
| Absolute pressure, lbs | 9.56 | 14.7 | 25. |
| Temperature, F | 193.2 | 212. | 240. |
| Temperature difference, Room = 70° | 123.2 | 142. | 170. |
| Coefficient (Mr. Donnelly's) | 2.08 | 2.112 | 2.226 |
| B.T.U. per sq. ft. rad. surf. per hour | 256. | 300. | 384. |
| Weight of steam per cu. ft.-lb | 0.0264 | 0.0379 | 0.0625 |
| Latent heat per lb. B.T.U | 979. | 966. | 946. |
| Steam condensed per sq. ft. rad. surf. per hr. (lb.) | 0.261 | 0.310 | 0.406 |
| Rad. surf. per lb. steam condensed per hr. | 3.91 | 3.33 | 2.60 |
| Sq. ft. rad. surf. for 10-in. pipe (Donnelly's) | 22,325. | 22,000. | 21,000. |
| B.T.U. in steam carried per hr | 5,716,200. | 6,600,000. | 8,064,000. |
| Steam condensed per hr.-lb | 5,839. | 6,832. | 8,503. |
| B.T.U. lost by radiation, 10-in. pipes, 1,000 ft. long (*a*) | 102,787. | 118,471. | 141,831. |
| Per cent. of heat carried | 1.80 | 1.79 | 1.76 |

(*a*) On basis of 0.3 B.T.U. loss by radiation per hour per sq. ft. of exterior of pipe per degree of difference of temperature, the pipe being well felted.

We thus see that by Mr. Donnelly's rules, a 10-inch pipe will supply from 5,839 to 8,503 pounds of steam at the two extreme pressures given. It would appear that the pipe size should be related rather to the quantity of steam to be carried rather than to the number of square feet of radiating surface to be supplied.

Let us take the figure 6,600,000 B. T. U. to be supplied to the radiator, which is the basis upon which both the radiating surface and the pipe size should be calculated:

| Pressures. | 10 in. Vacuum. | 0. | 10.3 lbs. |
|---|---|---|---|
| Sq. ft. of rad. surf. for 6,600,000 B.T.U. per hr | 25,781 | 22,000 | 17,188 |
| Lbs. of steam condensed | 6,744 | 6,832 | 6,977 |
| Lbs. steam carried by 10-in. pipe 1 oz. drop per 100 ft. | 4,674 | 5,778 | 7,342 |
| Lbs. steam carried by 10-in. pipe 1 lb. drop in 1,000 ft. | 5,916 | 7,314 | 9,294 |

The figures for pounds of steam carried are computed by the formula:

$$W = 60 \times 61.7 \sqrt{\frac{W(p_1 = p_2)d^5}{L}}.$$

According to this formula the 10-inch pipe will not carry the low pressure steam without allowing more drop than is stated.

An 8-inch pipe will, however, carry the required amount of

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steam for all the pressures named if a sufficient drop be given. Using the same formula with C = 60.8 we obtain

| | | | |
|---|---|---|---|
| Drop in 8-in. pipe lbs. per 1,000 ft..... | 3.91 | 2.86 | 1.81 |
| Av. temp. difference of pipe..... | 131.8 | 149.1 | 174.7 |
| B.T.U. loss by radiation per hr., 1,000 ft..... | 89,281. | 101,000. | 118,005. |
| Saving in radiation, B.T.U..... | 13,506. | 17,471. | 23,828. |
| Saving in radiation, per cent..... | 0.20 | 0.26 | 0.36 |
| Saving in weight of pipe, 1,000 ft. length, lbs.... | 11,880. | | |

The saving in radiation is a trifle, but the saving in weight of pipe is considerable, to which should be added the saving in insulation and in cost of valves, fittings, etc.

Mr. Donnelly says, "It is certain that the saving in first cost would not warrant the resulting decrease in efficiency," and again, "increase in velocity is always attended by a decrease in efficiency," but I fail to see that in the use of the drops stated for the 8-inch pipe there would be any decrease in efficiency whatever. In the case of the higher pressure, 10.3 pounds in the radiator, the steam pressure in the boiler would have to be 12.1 pounds if the pipe is 1,000 feet long, but the difference in efficiency of the boiler due to the increased pressure would be so trifling as not to be worth considering.

Prof. R. C. Carpenter: Prof. Kent, in his paper, states that heating engineers have not given the formulæ for flow of steam very much consideration, and this statement, I think, is not borne out by the facts.

In a paper read before the Institution of Civil Engineers, in 1879, by Robert Briggs, of Philadelphia, which paper is printed as one of Van Nostrand's Science Series, No. 68, there is given a number of tables for the flow of steam which are obtained by the use of various formulæ. They serve to show that all the formulæ give results through certain ranges which do not differ greatly, but for extreme positions there is a considerable variation. This rather serves to indicate that the use of any of the formulæ will give results which are probably practically correct for ordinary application. When we consider that the resistance in every case is assumed, the agreement is probably closer with each other, so far as the tabular results are concerned, than the hypothesis adopted in applying these results practically.

A French engineer, Ledoux, made some extensive experiments on the flow of steam, from which quite accurate values of the

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coefficients in the theoretical formulæ have been deduced. I at one time also checked up the value of these coefficients, obtaining essentially the same results. My own impression is that the flow of steam in pipes is most accurately represented by the following formula, of which the general form was first adopted by Prof. Unwin, the coefficients having been determined by experiment:

The loss of head,

$$p = 0.000131\left(1 + \frac{3.6}{d}\right)\frac{w^2 l}{ad^5}.$$

Discharge, in pounds per minute.

$$w = 87.45\sqrt{\frac{pad^5}{\left(1 + \frac{3.6}{d}\right)l}}.$$

Diam. in inches $d = 0.184\sqrt[5]{\frac{w^2 l}{pa}}$.

In the above formula,

p=loss of head in pounds.
l=length of pipe in feet.
d=diam. of pipe in inches.
a=density of steam or weight per cubic foot as given in steam table.

A table of the flow of steam in pounds, published in the Babcock & Wilcox catalogue, agrees very closely with the above formula. This table is not, however, of much use to heating engineers for the reason that the assumed pressure of steam is very high and the drop in pressure greater than allowable in good heating work.

Mr. J. A. Donnelly: I have gone over Briggs' figures, as figured on the Weisbach formula, and there are some velocities figured which no one could ever use in a steam-heating apparatus. It is all right for a flow of steam for something else, but not for successful steam-heating apparatus. The time has come, as Professor Kent says, when we want to be as correct as possible.

In regard to the Babcock table, I have figured that table and gone it over backwards and forwards, and it is figured on Unwin's formula. It is given in the book before the table and the table is figured by that formula.

I want to point out this comparison of Professor Kent's with the Wolff table. Wolff has figured on two per cent. drop of gauge

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for 100 feet with steam at 2 pounds, which is 4/10 of a pound, and it is on Unwin's formula, or what is called Babcock's formula. The table for steam at 5 pounds pressure is figured on a greater drop, as it is also two per cent. of gauge pressure. This gives 1/10 pound for 100 feet, or 1 pound for 1,000 feet.

Figuring on the Darcy formula, 1/10 pound drop, it is strange it comes to the the same amount with 16-inch pipe as 1 ounce drop with the Unwin formula. If Professor Kent had continued to 16-inch pipe, you would see the amount of radiating surface in his table would be the same as in the Wolff table.

I want to call attention to one thing in Professor Kent's paper: Table II, first column, .03 multiplied by 3.78 zero pressure, and the last column under 10.3 pounds pressure, 14,700 pounds per hour by 3.09, would bring an amount which is only 4 or 5 per cent. higher in radiating surface than the first column. So, if Professor Kent had carried that computation out, he would have seen that there is no necessity for figuring out these different amounts, because there is only a variation between the highest and lowest of 5 per cent. It bears out the statement made in my paper that varying pressure for the same drop practically produces constant radiating surface on the same size pipe.

Mr. R. P. Bolton: There is one matter connected with the subject about which I would like to say something, Professor Kent has referred to, and there is something to be said about the other side of the question. The actual capacity of work to be done is that figured on zero conditions. In New York we figure on zero conditions of the weather, conditions which obtain seldom and on very rare occasions. The economic results can be best obtained by the question of what can we afford to do on such rare occasions. We have about four days in the year when maximum conditions are reached here; that is when we have zero temperature. That does not obtain in the day time, but only in the very early hours of the morning, when the heat is at its lowest.

President Gormly: Of course, you know we are legislating for all parts of this country, and some parts of the country do have zero weather and for an extended period of time.

If Wm. J. Baldwin is present, he might give us some information on these lines.

Mr. Baldwin: I may throw some light upon one matter touched

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upon here to-night, namely: the first formula mentioned in Mr. Donnelly's paper for pipe diameters, $R = D^2 \times 100$. I believe I am responsible for that formula. I am responsible for it, so far as it is applied to heating apparatus at least. I think it was in 1878 that I adopted it. It says, in Mr. Donnelly's paper, "not figured for drop." It is rather late, after thirty years, to make an explanation; but I will say that in those days my practice and the practice of those who worked at that time was confined nearly altogether to the gravity-heating apparatus.

What I wrote then applied only to the construction of the gravity steam-heating apparatus, and I am not sure that any material change can be made from the sizes then suggested, if the apparatus is to be successful. I did have a "drop" in mind when I adopted this rule, and those who will read my first book carefully will notice that my sizes for pipe diameters were intended to give a uniform drop for an apparatus and not for a unit of length of pipe.

All formulæ in which the square root of the fifth power of the diameter is considered relate to the drop that will take place in a given length of pipe, under a fixed condition. If this unit of length is 25 feet and the distance or length of the pipe is doubled, the drop is doubled; and if the pipe length is increased 100 times the unit, the drop is increased 100 times. Now, this rule in the hands of a mathematician will determine the conditions that should exist at all parts of an apparatus, whether its pipes be large or small or irregular. A careful engineer can also lay out a system of piping by the Weisbach formula and tell very closely what the "drop" at the various points will be, and in modern apparatus, where steam is carried long distances, the engineer cannot work intelligently without it. Weisbach is credited with this formula, and if my memory serves me rightly, nearly everyone who has followed him on this subject has Weisbach for a foundation.

There is one consoling thing, however, in the various formulæ given by Mr. Donnelly, such as Darcy, Unwin, Kutter, etc., that they so nearly agree for the smaller diameters.

It must be borne in mind, however, that should a man design a gravity apparatus by any one of these rules with the intention of having a uniform drop throughout the apparatus, that he will find by the time he has nearly equalized the pressure in his return

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pipes, at or near the water line throughout his entire apparatus, that he will have mains whose diameters near the boiler will be much in excess of the diameters shown by the " Diagram of Carrying Capacities of Steam Mains with Various Formulæ " given in Mr. Donnelly's paper.

The first formula referred to in Mr. Donnelly's paper is the " straight-line formula," which is not, of course, in reality a straight-line formula. It simply happens to be represented by a straight line in his diagram, while each of the other formulæ is represented by a curved line. If the straight-line formula was properly represented, the radiating surfaces being equally spaced, it would be represented by a parabolic curve; and thus it is shown in the first edition of my book published about 1878. In a later edition of the book, in the same diagram, is shown a curve of the so-called Weisbach formula; the curve of the square being for gravity apparatus for buildings when the horizontal distances were long, while the curve of half the fifth power is shown for mains of buildings whose ground area is small, but whose height may be great, calling for considerable radiation on short mains.

For exhaust steam-heating apparatus, where there is no water-line or where the pressure at the water-line is not material, and where the entire endeavor is to proportion the mains of the apparatus sufficiently large, so that the total resistance will not cause too great a back pressure (say 1 pound), then the rule of the 2.5th power is good up to the point of the dissipation of the entire pressure that you command (say .1 pound or ½ pound). As soon, however, as the extremities of the lines begin to show a lack of appreciable pressure, then one of two things must be done. Either the mains must be increased in diameter near the source, or they must be increased at the extremities. Presumably, for equal distribution of pressure at all parts of the apparatus, the increase of diameters at the extremities would be best. In any case, the rule of the 2.5th power is destroyed and the ideal formula has yet to be put forth.

The formula, therefore, of $R = KD^2$ was put forth with the idea that a constant drop, would exist throughout all gravity-heating apparatus and be nearly equal for all its parts. I intended to give sizes for mains of a gravity apparatus that would give ½ pound loss of pressure between the boiler and the water lines in the apparatus, no matter how far they were from the boiler. The

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½ pound pressure, as you are aware, represents about 15 inches of hot-water column. My endeavor in those days—the early 70's—was to give sizes whereby the water in the vertical return pipes would not stand higher than 15 inches above the water line of the boiler. I had no means of giving careful scientific data, nor had I the time. The most I could do was to put water glasses on the vertical return pipes, of various rising lines in various heating apparatus, and note the losses of pressure at the various glasses. These losses were erratic. When the apparatus was in good running order, the radiators full of steam and the pressures steady the water would subside in the glasses and mark a steady condition. When this condition was about one foot higher than the true water level in the boiler I found that the 1-inch pipe, for *average building runs,* would take care of 100 feet of heating surface with a loss of something less than ½ pound of pressure (about 12 inches of hot-water column).

Fluctuations of pressure, however, such as always take place in a low-pressure steam-heating apparatus, supplied by a low-pressure boiler, complicated the matter. At times, on making a new fire, the pressure would drop down. When the new fire became active, the pressure increased. The reaction took place through the return pipes at once (they being full of water), while in the steam pipes there was a considerable loss of pressure due to the new steam hurrying through the pipes to fill the empty radiators. At such times the water would run up in the return pipes to a considerable height, often to 2 feet, and it was this fact that induced me to lay down a rule, that the lowest part of any steam main of a gravity steam-heating apparatus should be "at least 3 feet above the water line."

The normal condition of a gravity steam-heating apparatus, therefore, should be, that the water level in the poorest working return pipe should not stand more than 15 inches above the level of the water in the boiler. Under conditions of fluctuations of new fires, or starting the apparatus afresh, the water in the return pipes should not lift more than 2 feet above the water line in the boiler, the remaining foot being the "factor for safety" between the highest point in the return lines and the lowest point in the steam mains. Pipes of an apparatus that will not give conditions equal to these are too small in diameter, no matter what rule they are worked out by.

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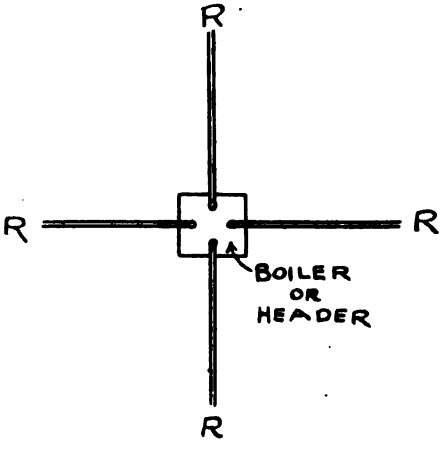
The mains of a steam-heating apparatus may be likened to the branches of a tree. The smaller branches are to be fed by larger ones. With the steam apparatus, pressures should be constant and nearly equal at all points. Constancy we may obtain, but equal pressures we cannot. There will be some loss in transmission, no matter how large we start, unless, indeed, we make a "tank system" in which the boiler is the center, and we run from it for about equal lengths and for equal heating surfaces (Fig. 1). This will be a balanced system—balanced in pressure—if the mains are equal lengths and equal surfaces; but as soon as we change our length or our heating surface a new condition sets




MR. BALDWIN'S SKETCH. FIG. 1.

in and we are forced to some good formula and have various diameter pipes for the various conditions. The use of the Weisbach formula is impracticable for the ordinary steam fitter; at least when the boiler has to be at one end of a building, and his mains become something like Fig. 2. Now, what he wants to know is how to find sizes for a condition like that shown in Fig. 2. If he places his boiler at " A," all to the right of " A " become the mains of a small apparatus and the " drop " at the end of the three subdivisions " R," " R," " R " will be the same, provided the three branches " R," " R," " R " are the same, regardless of the diameter of the pipe " a." If the pipe " a " is small, the " drop " between the boiler " A " and the cross is great, but the distribution beyond this point is equal. Now, if " a " is made large, the " drop " can be reduced to a negligible quantity.

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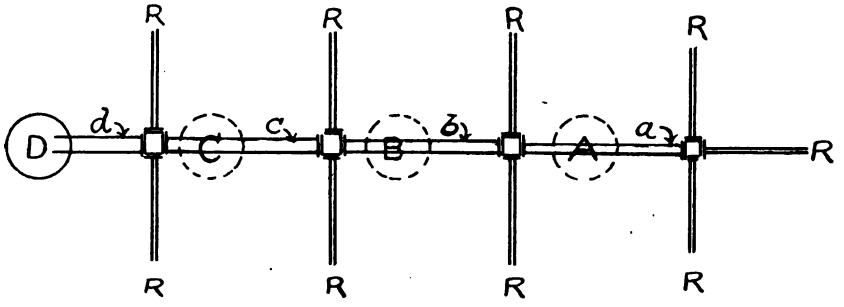
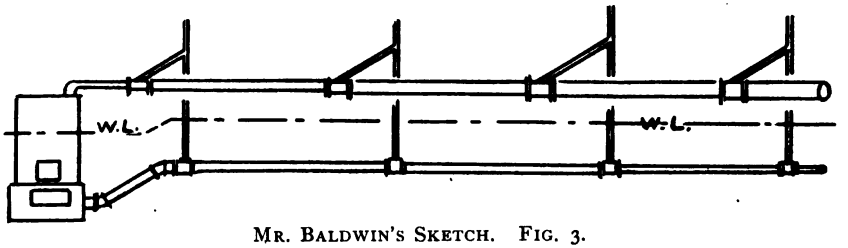
Now move the boiler to "B." The work is nearly doubled, as well as the distance, and if you are to keep up the pressure, the pipes "b" and "a" must be large—so large that the friction loss or "drop" is still negligible.




MR. BALDWIN'S SKETCH. FIG. 2.

In like manner move the boiler to "C" and to "D," and the trunk main "a," "b," "c" and "d" should be made so large in diameter that the friction loss within it will be inconsiderable. If this is done, all the points "R," "R," etc., will have nearly equal pressures, so that practically the pressure at each extremity will be the same.

One thing must be borne in mind, however, that, no matter how large the trunk main "d," "c," "b" and "a" is made, there will be some "drop," and this leads us to the question as




MR. BALDWIN'S SKETCH. FIG. 3.

to why it would not be better to reverse our main and put the small end to the boiler, as in Fig. 3. This will insure us a more equal distribution of both steam and pressure than our present practice. Of course you will say it is not practicable. I agree with you, although I desire to call your attention to the "loop of constant diameter" now so often used, by carrying a main of constant diameter around the building.

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This is not turning the small end of the pipe to the boiler, but it is an effort to get equal, or nearly equal, pressures at all parts of the horizontal main by maintaining the size of the pipe throughout its run.

To find the drop in this main circuit, the formula $R = KD^{2.5}$ can be utilized; but when we get to the vertical pipes, the velocities of the steam rather than the drop in pressure must be taken into consideration, particularly one-pipe rising lines.

In connection with rising-line sizes you must follow something like the "straight-line formula" (in single-pipe work, at least, if not in double), because the velocity of the steam passing up the riser has to be sufficiently slow so as not to carry up the condensed steam.

In working out a plant for any high building in New York, the horizontal main about the cellar can be laid out by any formulæ that will give nearly constant pressure at all points. When it comes to the rising line you must go by a formula that will give a pipe so large that it will not hold up the water.

As a result of investigations, I have come to the conclusion that when I get a velocity of 45 feet per second in a rising line I am reaching the danger point. At 50 feet I think I have reached it. When it comes to a horizontal one-pipe radiator connection I have found nothing to go by. A 1-inch pipe, however, I think, will, under favorable conditions, take care of 40 square feet of radiating surface. One conclusion I came to in my experiments was, that in the case of a horizontal pipe a velocity of 15 feet per second, under favorable conditions, is probably safe.

In connection with the descent of the water of condensation in a rising line, Mr. Donnelly assumes that it falls in drops like raindrops, or in drops even as large as ¼ of an inch in diameter. In my experiments with a glass-rising line I found water running in spirals and clinging to the pipe, and at the end it would break away and come down in a shower or jet.

When I first noted what took place in a horizontal pipe it appeared to me that the steam and the water were running up the pipe; but as the radiator kept dry I began to realize that the water was not running to the radiator. The pipe was nearly one-third full of water. The steam passing to the radiator had some influence on the water coming down. There was a wave running with the steam along the top of the water in the pipe, which made me

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think at first that the water was not running back; but on close examination I noticed black specks moving in the opposite direction, at rather a high velocity, near the bottom of the pipe, in other words, a return current at the bottom of the stream.

Mr. R. C. Taggart: Some time ago Mr. Baldwin and myself carried out certain experiments, in order to determine with what velocity steam at about atmospheric pressure could pass through a pipe and still allow the water of condensation to readily return. Experiments were also made where air was forced up through a pipe, while water was falling in an opposite direction. The weight of the water and the weight of the air were made approximately equal. In other words, the relative weights of the gas and liquid were similar to what would be found in a one-pipe steam-heating apparatus.

The results of these experiments showed that in moderately large vertical pipes (3- and 4-inch pipes) it was possible for the velocity of the ascending steam to be as much as 50 feet per second without interfering with the return of the condensed steam as it falls down within the pipe. With smaller pipes the velocity of the ascending steam in vertical pipe risers should not exceed 30 to 40 feet per second; and in very small pipes (¾-inch and 1-inch) it is better to figure on a still lower velocity. It is possible, however, in relatively small pipes, to obtain a velocity of 50 feet per second and still return the water of condensation under favorable conditions. Most of the experiments were made with pipes of relatively small diameters, and in the case of the 3- and 4-inch pipes the experiments did not include velocities much above 50 feet per second.

In regard to the "drop" in pressure in one-pipe risers I might say that the "drop" in pressure is of no particular importance, so long as we have pressure enough at each radiator for the steam to force out the air. Primarily, the size of the vertical risers should be fixed by the velocity of the steam which may be allowed rather than by the drop in pressure.

In gravity apparatus the loss in pressure in the main pipes must be comparatively small, so as to allow the water of condensation to readily return to the boiler. A loss in pressure within one-pipe vertical riser will not, however, prevent the water of condensation from returning to the boiler, provided the velocity of the steam within the pipe does not hold up the return water.

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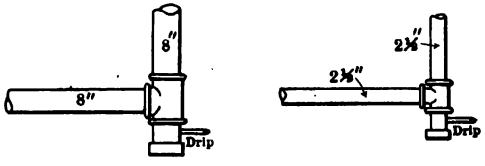
Mr. Baldwin: I recommend to every one here the name of Robert Briggs. He is the man who is responsible for the threads we have on our gas and steam pipes. The Briggs' formula, adopted by the Society of Mechanical Engineers (on whose committee I had the honor to serve), has become the standard in this country for pipe threads. Robert Briggs was an able man, indeed. Forty to fifty years ago he gave consideration to the construction of fans, and any one visiting Washington will find the old fans still in operation in the capitol that were constructed by Robert Briggs. He worked on the question of fans and his formula for centrifugal fans has become national.

President Gormly: Any other remarks? If not, we will proceed to some of the topics.

Mr. J. A. Donnelly: I would like to show the members a little puzzle in piping.

We will suppose that the accompanying diagrams (Figs. 1 and 2) represent two steam mains under practically the same condi-




MR. DONNELLY'S SKETCHES. FIG. 1 AND FIG. 2.

tions. One of them is an 8-inch main, and the other a 2½-inch, both being dripped in the same manner.

The puzzling condition is this: Whenever the drip from the 2½-inch main becomes obstructed by dirt, the radiation supplied by it fails to heat and the drip must be cleaned before it resumes. Some time ago it was necessary to make a change in the drip piping from the 8-inch pipe, and when it was disconnected it was found to be completely stopped by dirt and had evidently been in that condition for some time. It was then observed that the 8-inch main apparently worked as well without the drip connected as with it.

The engineer asked me for my explanation of this and I found one satisfactory to myself, but I would like to do some experi-

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menting before I feel sure that I have the correct solution of the problem.

In regard to velocities which Mr. Baldwin speaks of it is quite remarkable that his figures agree so closely with those I have given, as I had no conception of the experiments he has carried on. It is quite remarkable that the statement I made that 50 feet per second velocity would carry water up should agree so closely with his experiments that 40 to 45 feet per second was the highest velocity permissible. My statement that 10 to 15 feet per second was the maximum velocity allowable in radiator connections agrees closely with his, that 15 feet would be the maximum velocity. Mr. Baldwin's description of designing a one-pipe heating system, figuring the risers and radiator connections on maximum velocity and the main on drop in pressure, puts before me clearer than ever before what I consider is the best way to lay out a one-pipe system.

Mr. Baldwin speaks of drops of water and their diameter. I could not find anything anywhere that would tell me how big a drop was and so I started to find out for myself. I started the faucet to dripping (about 100 drops per minute) and counted, and I found a teaspoon contained about twenty, a tablespoon about 100, 4,000 to a pint, and 32,000 to a gallon. I counted as many as would fill a half-pint measure, so I can assure you that it is nominally correct. Figuring as to the cubical contents of a sphere, with drops ¼-inch in diameter, it would figure 28,239 to the gallon. It is near enough for our purpose; that drops dropping from ordinary surfaces are a trifle less than ¼-inch in diameter.

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## CLXXII.

# TEMPERATURES FOR TESTING INDIRECT HEATING SYSTEMS.

BY W. W. MACON.

(Non-member of the Society.)

Presented by request.

The object of this paper is to offer values of temperatures for use in testing indirect heating systems during periods when the zero weather conditions for which the system is designed are not existing. When a given indirect heating system is operated under the conditions which are expected to obtain in zero weather at a temperature out of doors that is something different from zero, a definite temperature within doors should be realized depending on the outdoor temperature. The need of figures of this description has been expressed from time to time as something which will enable the contractor to assure the buyer of a system that the stipulations regarding the maintenance of a specified temperature in zero weather will be amply fulfilled. In other words it is stated that it should be possible to test a plant during relatively mild weather and from the results determine whether or not the plant has been properly designed, though the opinion is strong, in opposition to such a need, that acceptance of a heating plant should not be contingent on the results of a test, but should be independent of any such question at all, the reputation of the engineer sufficing to guarantee satisfactory performance until actually proved otherwise.

As a contribution to the Society's literature on the subject, the present paper is suggested as supplementary to the first paper presented to the first meeting of the Society twelve years ago by Prof. J. H. Kinealy, entitled "Determining the Heating Power of Heating Systems," and as supplementary also to the "Code for Testing Direct Radiation Heating Plants," submitted by a committee of which Professor Kinealy was chairman, and printed

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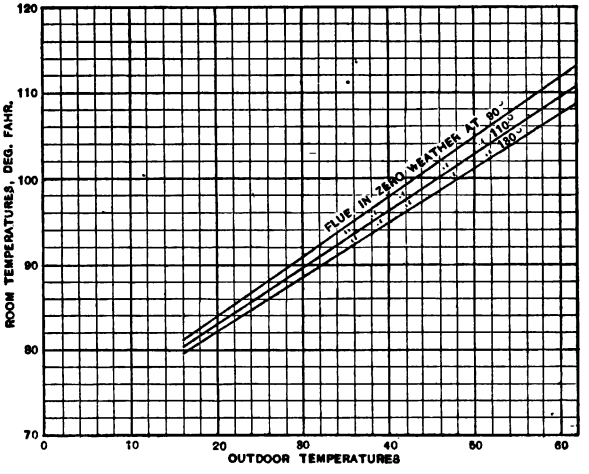
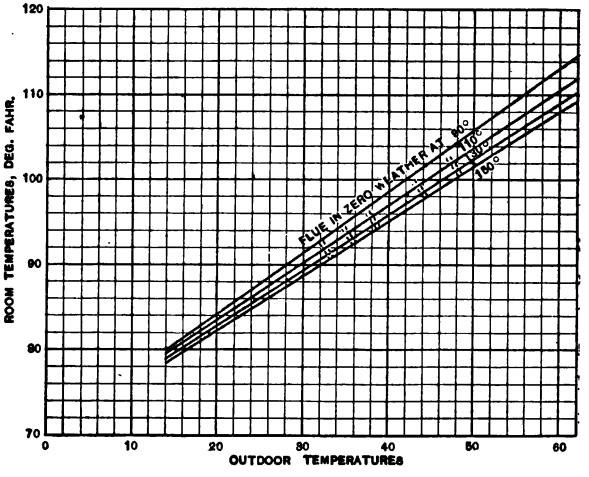
in Vol. IX. of the Society's "Transactions." Both Professor Kinealy's paper and the committee report treated solely of direct




INDIRECT HOT WATER RADIATION—WATER AT 200 DEGREES.

radiation, while the present discussion is designed to cover indirect radiation—steam as well as hot water, and, though with some question, the furnace system of warming. As an examina-




INDIRECT STEAM RADIATION—STEAM AT 2-POUND PRESSURE.

tion into the operation of indirect heating the paper is submitted as continuing the subject treated in the Society's initial paper.

The considerations involved in the temperature determination

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are in brief as follows: When the indirect radiator heating medium, as steam or hot water, is turned into the radiator and the radiator starts emitting heat, the air immediately surrounding it becomes warmed. The result is an expansion of the air with consequent relative rarefaction or diminution in density. The air outside being heavier per given volume and both inside and outside being under atmospheric pressure, the weight of the outside air overbalances that inside and the warmed air is pushed upward. The cooler air in the process of displacement then becomes warmed and the column of warm air becomes higher, so that the force, though actually small as compared with other forces encountered in engineering, becomes greater, resulting in successively higher velocities. When the flue from the radiator becomes filled with warm air, the tendency for the speed to keep on increasing will be finally checked by the fact that the increases in speed result themselves in a lowering of the temperature and thus in turn in a lowering of speed. As the air passes over the indirect heating surface the temperature which it attains is dependent on the speed, the higher the speed the less the final temperature (though the amount of heat absorbed increases). The air thus assumes a definite temperature which in connection with the outside temperature results in a definite velocity of flow, and this in turn results in the passage over the radiator in a given time of a definite quantity of air, and it is this quantity of air which the radiator is able to heat to the temperature in question. In short an equilibrium among velocity, heat emitting capacity and outside and flue temperatures becomes established.

The first stage in the calculations required the determination of this flue temperature and had to take into account the varying amounts of heat that an indirect radiator will give off according to the speed of the air over it and the varying capacity for heat of a given volume of air depending on its density or weight per cubic foot.

The second stage of the calculations comprised the determination of the temperature a room would attain for a given outside temperature with the apparatus operated as though zero weather were at hand, use being made of the value of the flue temperature calculated in the first stage. The flue temperature in question will bring about the delivery into the building of a definite amount of air, which heated from the outside temperature to the flue

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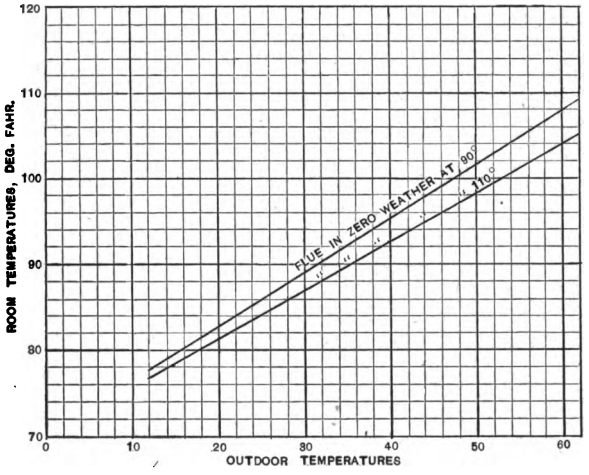
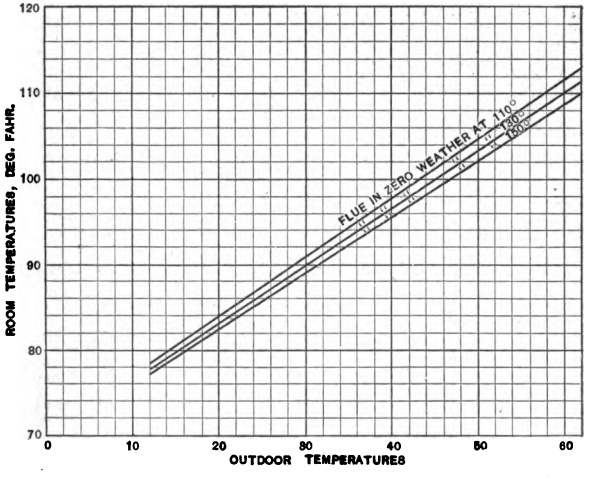
temperature means the delivery of a definite amount of heat in a given time. Before the amount of air involved in the particular




INDIRECT HOT WATER RADIATION—WATER AT 160 DEGREES.

case has succeeded in escaping from the building after delivery to the rooms, the temperature of the air is decreased from the flue temperature to a temperature within the rooms that is the




INDIRECT STEAM RADIATION—STEAM AT 5-POUND PRESSURE.

temperature sought in the second stage of the calculations. In cooling from the flue temperature to this room temperature the air loses a definite amount of heat which is the amount that the

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exposed walls and windows of the rooms can carry away under the temperature difference between the inside air and the outside air.

## RESULTS.

Before explaining the operations involved in the calculations of both the first stage and the second stage, reference may be made to the results and to their application. Six different conditions of the indirect radiator were first considered in solving for the values of the different temperatures, three for steam indirect radiators and three for hot water indirect radiators. In the case of the steam radiators, the use in the radiator in zero weather of steam at 5 pounds above the atmosphere was considered and steam at about 2 pounds above the atmosphere and at atmospheric pressure, in other words the use of steam at 227, 218 and 212 degrees respectively. In the case of the hot water radiators three temperatures of water were selected, 200, 180 and 160 degrees.

For each temperature of the heating medium, that is, for the range of six temperatures from 227 to 160 degrees, a figure was adopted for the probable temperature which the air in the flue would assume in zero weather. For example, with steam at 227 degrees, three flue temperatures, 150, 130 and 110 degrees respectively, were employed in the examination, and in the case of water at 160 degrees, two flue temperatures, 110 and 90 degrees. This is in a measure assuming that the engineer designs an indirect system in part on the basis of a definite flue temperature, knowing that with certain radiation assembled together with a certain proportion of open or free spaces for the passage of the air, the depth of the radiator in connection with the temperature of the steam or hot water will heat air admitted at zero to the accepted flue temperature. In each case calculations were made to ascertain the flue temperature when the air outside was at 20 degrees, at 40 degrees and at 60 degrees, and finally to ascertain the corresponding room temperatures. The results are shown in the accompanying set of charts. These show the relation between outside temperature and inside temperature, three for indirect steam radiation and three for indirect hot water radiators.

The use of the charts will be something as follows: If it is assumed that a system has been designed to warm satisfactorily

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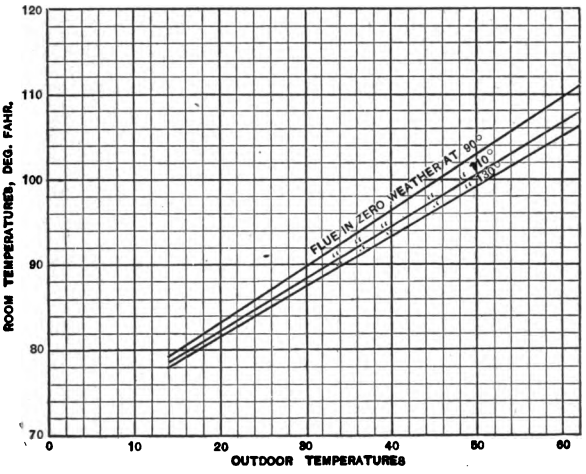
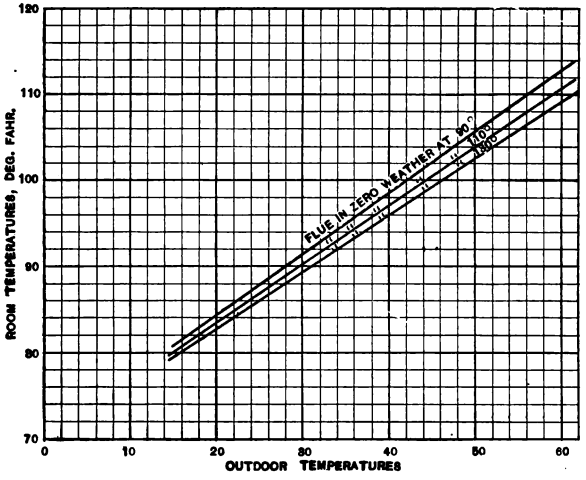
with steam at 2 pounds pressure with a flue temperature in zero weather of 120 degrees, and the test is made when the tempera-




INDIRECT HOT WATER RADIATION—WATER AT 180 DEGREES.

ture outdoors averages 25 degrees, reference is made to the chart for the steam radiator working with steam at 2 pounds pressure.




INDIRECT STEAM RADIATION—STEAM AT ATMOSPHERIC PRESSURE.

Running vertically on the line above 25 one will find a point about half way between the two lines marked 110 and 130, and then reading horizontally will find that the temperature in the

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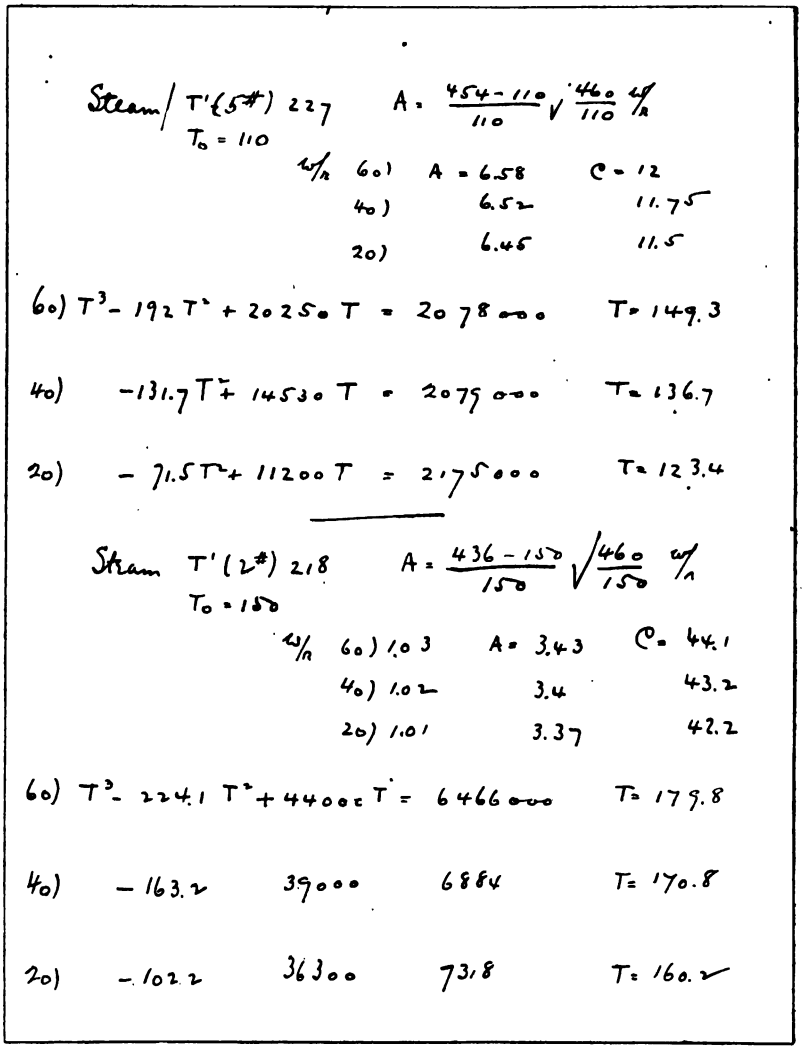
room should average between 86 and 87 degrees if the apparatus can be trusted to work rightly in zero weather.

If one had planned to employ a temperature of steam or hot




SAMPLE SHEET OF CALCULATIONS SHOWING FLUE TEMPERATURE DETERMINATIONS

water in the indirect radiator in zero weather different from any given in the charts, one could find the room temperature for a radiator temperature both above and below that in mind, choosing the value of the room temperature from the two values obtained. Take the case of a hot water radiator designed for water at say

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205 degrees and a flue temperature of 120 degrees to be tested at 20 degrees. For a hot water radiator at 200 degrees and for 120 degrees flue temperature, the room would be at 82.5 degrees. Reference can then be made to the chart for the 212 degree steam radiator, when the room temperature will be found for the same zero weather condition to be 83.5 degrees. The probable temperature is thus about 83 degrees.

In this connection it must be noted that there is exhibited an apparent refinement of the temperature values. When the variation in methods of taking temperatures in the actual case is remembered as well as the variation in the records of the temperature, any necessity to interpolate in the manner explained seems rightly questionable. The only inference is that a close approximation to the temperatures should be realized, as the values for any one basis of design are close to those for any other basis of design, and if the temperatures charted cannot be reached in the test, there is question about its satisfactory capacity. This paper of course does not aspire to the scope of a code and no opinions regarding temperature measurement are vouchsafed.

In the foregoing it is assumed as stated that the system is designed on the basis of having the indirect radiator in zero weather at a certain temperature and obtaining the heated air at a certain temperature. If such a practice is not followed, it can be assumed that the engineer knows from experience with other of his systems that with a definite steam pressure or water temperature the air is usually delivered at a certain temperature. Though he may lay out a system without reference to the flue temperature a knowledge of its ordinary value assists in determining a proper test temperature.

## ON THE DESIGN OF INDIRECT SYSTEMS.

An interesting point brought out by the charts is the high room temperatures that result in moderate weather with apparatus designed to give low flue temperatures in zero weather. For example, as noted on the chart for the hot water radiator at 180 degrees, higher room temperatures are indicated if the air is heated to 110 degrees in zero weather than if it is heated to 130 degrees. This means that when a system is designed to heat a specific building with 110 degrees flue temperature as against one

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with 130 degrees flue temperature a greater volume of air must be supplied in order to do the work, as the range of temperature that the air can be cooled to 70 degrees in zero weather is less in the case of 110 degrees than in the case of 130. In other words ventilation is secured in a greater ratio with a flue temperature at 110 degrees than with the flue temperature at 130, and greater ventilation means the escape of a greater amount of air, all of which has been heated from zero to 70 degrees. This is repeating what has already been said, that a given indirect radiator that heats the air to 110 degrees as against 130 is having the air passed over it at a higher rate of speed and is giving up a greater amount of heat per unit of surface than when the temperature of 130 degrees is obtained. While the increase in temperature is not so great the volume of air is that much greater, so that the total amount of heat, as represented by the weight of air multiplied by the range of temperature, is greater than that with the less amount of air heated through the greater range of temperature.

This relates to a matter of indirect radiation that is perhaps altogether too little understood, and that is the desirability of designing such systems on the basis of flue temperatures. It is commonly assumed that because one flue goes to the third story and another goes to the first the velocity in the higher flue, being greater, will bring about a greater amount of heat transmission from the indirect radiator. If the radiator, however, is of proper depth it will be able to raise the air in zero weather to say 150 degrees without regard to the height of the flue. The amount of air to heat the given room when delivered into the room at 150 degrees determines the amount of heat required and therefore determines the size of the indirect radiator. Increasing the size of the radiator simply increases also in proportion the free area of cross section for the air passage so that the actual velocity of the air over the radiator is not increased, but is kept constant. The fact that the velocity is greater the higher the flue simply makes it possible to reduce the area of that flue according to the height of the flue and according to the amount of air that the flue must deliver.

The value of designing on this basis was recently explained at length in *The Metal Worker* by Mr. E. T. Child, in an article which gave charts and tables to show how to determine the sizes

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of radiation and flues for indirect heating with both steam and hot water. Mention is made at this length because of the widely varying and empirical methods of laying out indirect radiation, which methods are all right so far as ordinary or average systems go, but which are apt to fail when the unusual plant is to be designed. It is probable that the methods advocated by Mr. Child are those in use among some heating engineers, but they have seen fit to keep the information largely to themselves or have never been asked for it.

## RULE FOR FINDING THE TEMPERATURES.

A rule instead of the charts can be used for finding the room temperatures and is as follows:

Multiply the outside temperature in degrees Fahrenheit by a factor given in the following list and add 70 to the product, when the sum will give the room temperature which should be reached by the system. The factors are given for different temperatures in the indirect radiator and for different temperatures in the flue on the zero weather basis:

| | Factor. |
|---|---|
| For steam at 5 lb.: | |
| Flue in zero weather at 150 deg. | 0.63 |
| " " " 130 " | 0.66 |
| " " " 110 " | 0.69 |
| For steam at 2 lb.: | |
| Flue in zero weather at 150 deg. | 0.63 |
| " " " 130 " | 0.65 |
| " " " 110 " | 0.68 |
| " " " 90 " | 0.72 |
| For steam at atmospheric pressure: | |
| Flue in zero weather at 130 deg. | 0.65 |
| " " " 110 " | 0.67 |
| " " " 90 " | 0.71 |
| For water at 200 degrees: | |
| Flue in zero weather at 130 deg. | 0.61 |
| " " " 110 " | 0.66 |
| " " " 90 " | 0.70 |
| For water at 180 degrees: | |
| Flue in zero weather at 130 deg. | 0.58 |
| " " " 110 " | 0.61 |
| " " " 90 " | 0.66 |
| For water at 160 degrees: | |
| Flue in zero weather at 110 deg. | 0.56 |
| " " " 90 " | 0.62 |

For an example, suppose it is desired to know the temperature of the room if the system has been designed to operate in zero weather at a water temperature of 190 degrees and under these conditions the flue temperature is found to average 125 degrees. For water at 200 degrees, the factors are 0.61 and 0.66 for 130 and 110 degrees flue temperature respectively, so that for 125 degrees flue temperature the probable factor is about 0.62. For water at 180 degrees, the corresponding factors are 0.58 and 0.61, so that for 125 degrees flue temperature the factor is about 0.59. For water at 190 degrees the factor is the mean of 0.62 and 0.59, or about 0.605. If the outside temperature is 27 degrees the inside temperature corresponding is $70 + 0.605 \times 27 = 86.3$ de-

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grees. The same result can be obtained quicker by use of the charts.

## HOW THE FIGURES WERE OBTAINED.

In the calculations by which the temperature values were determined the following symbols have been employed:

$U$ = B.T.U. per sq. ft. of indirect radiator per hour per degree difference between the temperature inside and outside the radiator, for the velocity which obtains in zero weather.

$r$ = ratio or coefficient to take into account the variation of the value of $U$ for different velocities, so that

$rU$ = B.T.U. per sq. ft. per hour degree difference of temperature for a given velocity.

$R$ = the number of sq. ft. of radiation.

$H$ = the B.T.U. per sq. ft. of radiation per hour.

$RH$ = the total amount of heat given off by the indirect radiator.

$v$ = the velocity of the air in the flue in feet per minute.

$F$ = the area of the flue in square feet.

$f$ = the friction factor by which the theoretical velocity is multiplied to get the actual, which is thus $fv$.

$Q$ = the volume of air per hour in cubic feet.

$w$ = the weight of the air at the temperature of the air outdoors multiplied by the specific heat of air.

$t$ = the outside temperature (degrees Fahrenheit).

$T$ = the temperature of the air in the flue.

$T^1$ = the temperature of the steam or hot water in the radiator, as the case may be.

$h$ = height of the heated flue in feet.

As the amount of heat that a radiator will give off per degree difference must be multiplied by the difference between the temperature of the radiator and the mean temperature of the air passing over it,

$$H = rU\left(T^1 - \frac{T+t}{2}\right),$$

and the total heat given off is as follows:

$$RH = R_rU\left[\frac{2\,T^1 - (T+t)}{2}\right] \quad . \quad . \quad . \quad . \quad (1)$$

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The heat given off by indirect radiator is utilized in warming $Q$ cubic feet of air through temperature range of $T - t$, so that

$$RH = w\,Q\,(T-t).$$

As $Q$ is equal to $vF$, and as the velocity in the flue is

$$v = f\sqrt{\frac{h\,(T-t)}{460+t}},$$

the total heat absorbed by the air is as follows:

$$RH = w\,f\,F\,(T-t)\sqrt{\frac{h\,(T-t)}{460+t}} \quad . \quad . \quad . \quad . \quad (2)$$

The total heat given off by the radiator is taken up by the air passing over it, so that equating the two expressions (1) and (2) the following equation is obtained:

$$\frac{R\,r\,U}{2}\,[2T^1-(T+t)] = w\,f\,F\,(T-t)\sqrt{\frac{h\,(T-t)}{460+t}}.$$

For the conditions which obtain at zero the equation is naturally similar, and is as follows:

$$\frac{RU}{2}\,[2T^1-(T_0+t_0)] = w_0\,f\,F\,(T_0-t_0)\sqrt{\frac{h\,(T_0-t_0)}{460+t_0}}.$$

If the corresponding terms of the first equation are divided by the second, the equation takes the form of

$$\frac{r\,[2T^1-(T+t)]}{2T^1-(T_0+t_0)} = \frac{w\,(T-t)}{w_0\,(T_0-t_0)}\sqrt{\frac{(T-t)\,(460+t_0)}{(T_0-t_0)\,(460+t)}}.$$

It will be seen that if it is assumed that the heat from an indirect radiator is not all taken up by the air, but that a loss of say 5 per cent. is occasioned through radiation into the cellar, and so on, any factor allowing for this loss would be eliminated in the division so far as the last equation is concerned. It will be seen also that the same coefficient for the loss of velocity by friction is employed in the zero weather conditions as in the other conditions. It can be shown that the loss by friction is a constant or at least a practically constant factor of the theoretical velocity.

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The last equation takes the following form:

$$T^3 - (3t + C)\,T^2 + [3t^2 + C\,(4T^1 - 2t)] = C\,[4T^1\,(T^1 - t) + t^2] + t^3, \quad . \quad . \quad . \quad . \quad . \quad (3)$$

in which $C$ is equal to

$$\frac{460 + t}{A},$$

in which $A$ is equal to the following expression:

$$\frac{2T^1 - (T_0 + t_0)}{T_0 - t_0} \times \frac{w}{rw_0}\sqrt{\frac{460 + t_0}{T_0 - t_0}}$$

It is from equation (3) that the values of the flue temperatures were obtained. It will be noted that expression $A$ contains the factor $r$ and the factor $w \div w_0$. Assuming both of these factors equal to unity, trial values of the flue temperature were obtained, and from these the probable relative velocities ascertained. From a record of tests of the effect of velocities on indirect radiation, as given in Prof. R. C. Carpenter's book on "Heating and Ventilating Buildings," an approximate value of $r$ was obtained in terms of the outside temperature as follows:

$$r = 1 - 0.0015\,t.$$

In a similar way from tables giving the weight of air at different temperatures, the values of the ratio $w \div w_0$ were obtained, and this ratio, subsequently designated simply as $w$, was obtained also in terms of the outside temperature as follows:

$$w = 1 - 0.001\,t.$$

In the short time in which it was necessary to make the calculations of this paper the values of these ratios were employed for all cases, although, to be more strictly accurate, it would have been desirable to modify them slightly for the hot water radiation. The ultimate results would probably not be changed more than one or two degrees with 60 degrees temperature outdoors and of course much less at the outside temperatures present in any test.

The procedure in determining the temperatures was in brief as follows: For a given temperature of the heating medium, $T^1$, and for the given temperature of the flue temperature at zero, $T$, the value of $A$ was first determined for the three temperatures

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of 20, 40 and 60 degrees, as shown in the sample calculation sheet included in the paper.

This and the rest of the work was done largely with the use of the slide rule. The hair line was placed opposite the value of $A$ on the lower scale and the reading on the upper scale gives its square. Dividing this by means of the slide by $460 + t$, which is 520, 500 and 480 in the three cases, a number is obtained which it is easy to take the reciprocal of on the slide rule, the reciprocal being the value of $C$. In substituting the value of $C$ in equation (3) the equations noted on the calculation sheet are obtained. This gives an equation of one variable of the third degree, which expression, however, is not a perfect cube. It was therefore solved by a try method. A little practice would enable a close approximation to the probable value of $T$, and with the slide rule the value of the equation with this assumed value was easily obtained. If the first member of the equation with this assumed value gave a total which was greater than the second member of the equation, a value less than that first selected was taken and the first member again evaluated. Assuming that this showed a total somewhat less than the second member, by interpolation it was impossible to determine the value of $T$ with one decimal point.

The determination of the value of inside temperature was in part as follows, with the use of the additional symbols:

$t_1$ = the temperature of the room air.

$E$ = the equivalent glass surface, or better, the amount of heat that the walls and windows together will transmit for one degree difference in temperature between the room air and the air outside. Then the loss of heat by the air admitted into the rooms is

$$w\,Q\,(T - t^1).$$

This is equal to the loss of heat transmitted by the walls and windows, which loss is as follows:

$$E\,(t^1 - t),$$

then

$$wQ\,(T - t^1) = E\,(t^1 - t).$$

At zero degrees the equation is

$$w_0 Q_0\,(T_0 - 70) = E\,(70 - 0).$$

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Dividing the members of the first equation by corresponding members of the second equation and simplifying the equation takes the form of

$$\frac{w}{w_0}\sqrt{\frac{T-t}{T_0-t_0}\times\frac{460+t_0}{460+t}}\cdot\frac{T-t^1}{T_0-70}=\frac{t^1-t}{70}.$$

In this let

$$\frac{w}{w_0}\sqrt{\frac{T-t}{T_0-t_0}\times\frac{460+t_0}{460+t}}=D,$$

so that the equation, solving for the room temperature, can take the form of

$$t^1=\frac{70\,(D\,T-t)+T_0\,t}{T_0+70\,(D-1)}. \quad . \quad . \quad . \quad . \quad . \quad (4)$$

The procedure in this case is the determination of $D$ and simple substitution in equation (4).

DISCUSSION.

Mr. Macon: A thing I did not bring out in the paper will be noticed if one looks at the charts closely, and that is, the inside room temperatures will not greatly differ for different flue temperatures and the like. The practical difficulty in measuring temperatures in a room are so great it is probable all these results should be brought into one equation, instead of having, as on p. 83, a list of factors. Perhaps, an average of these would be abundantly practical. For example the inside temperature should always be approximately $70 + 0.65\,t$, $t$ representing the outside temperature. Then, for example, with 40 degrees outside, the inside test temperature should be about $70 \times 0.65 \times 40 = 96$ degrees.

Returning to this matter on pp. 81 and 82. It seems entirely practicable to design indirect heat apparatus on flue temperatures. And in looking over the subject in different authorities, it would seem that one of the factors involved in the operation of indirect radiation is forgotten. Other things being equal, the higher the flue naturally the greater the velocity. The greater the velocity of the air the greater the amount of heat given off per square

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foot of radiator. The result is, for the third-story room as compared with the first-story room, the amount of indirect surface can be decreased. But you will, also, find the amount of air supplied is decreased, and in such a proportion is the amount of air from the radiator decreased that you will not get so much heat from the radiator as you might suppose with the higher flue.

Mr. Donnelly: I want to ask Mr. Macon what is the limit of the inside temperature which this table, on page 10, for instance, includes. I should surmise this test is to be made at quite a high temperature in the room, say, 60 degrees, for a hot water or steam radiator as the case may be. It seems to me there must be a limit to the range of applicability.

Mr. Macon: The question Mr. Donnelly asks is best answered by saying that it is a subject that should come under the jurisdiction of the Committee on Tests. The code that was submitted by this committee is referred to in the paper. It is suggested that it would be unwise to carry on any test when the outside temperature was much, if any, above 40 degrees. The idea is that the rate of heat transmission per degree difference in temperature is not necessarily a constant factor, but is less the less the difference between inside and outside temperature. This would answer Mr. Donnelly in saying that it would not be expected that any of these coefficients should be multiplied by any temperature figure higher than 40.

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## CLXXIII.

# DERIVATION OF CONSTANTS FOR BUILDING LOSSES.

BY R. C. CARPENTER.

(Member of the Society.)

I am very glad to see progress within the last few years in the use of scientific formulæ for designing heating and ventilating apparatus, and this progress has been greatly aided by various scientific papers read before this Society. In a few years, I believe, the "rule of thumb" at present in use to a considerable extent will drop out of use entirely and be replaced by rational scientific methods. I believe that engineers in our work now generally recognize the fact that practically all phenomena relating to the transfer of heat fall under general laws of nature which can be expressed by rational formulæ. It is also recognized that in the application of such laws or formulæ "coefficients" connecting the theoretical with the practical are necessary and must be applied. This paper deals with the origin of such coefficients as are applied to determine the transfer of heat through walls and windows of buildings.

In the calculation of radiating surfaces and the various elements of our heating systems we employ certain constants. It is a matter of very great interest to ascertain how those constants were found, and whether they rest on a scientific basis of measurement or merely depend upon the estimate of designers.

The above statement might indicate that I was able to give you definite information as to the origin of many of these constants. I am sorry to state, however, that such is not the case. My object in presenting the paper is merely to call attention to the actual state of our knowledge, hoping that it will bring out, at later meetings if not in this one, the information desired.

At the August meeting of the Society, Walter Jones of Stourbridge, England, read a valuable paper entitled "Heat Losses

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and Heat Transmission," in which he compared the different coefficients for building losses as given by various authorities. This comparison indicated that the authorities differed greatly as to some coefficients, but were in quite close agreement as to others.

Some years ago I tried to find what actual experiments had been made for determining these various coefficients. The result of this investigation indicated that practically all of our coefficients for heat losses and heat transmissions resulted from experiments made by Péclet in France, about 1860, and, further, that so far as I could ascertain these were the only original experiments which completely cover the field. These experiments are described in Vol. I, Traite de la Chaleur, E. Péclet, Paris (1st edition, 1863; 4th edition, 1878). I have published in the fourth edition of my work on Heating and Ventilating, a translation of that portion of Péclet which relates to heat transmission through radiators and buildings; this I will append to my paper for convenience of reference. There is not available a translation of Péclet in English. Various authorities using different languages, in applying Péclet's experimental values to different conditions have obtained slightly different results, partly due to difference in assumed conditions and partly due to errors in the translation. This in a large measure accounts for the difference in the various coefficients as given by different authorities.

There is no doubt that in some cases coefficients had been deduced from rules of practice or rules of thumb, but such coefficients have not generally been of a scientific form nor have they been widely used.

In the English work on Heat by Box, numerous examples of the application of Péclet's coefficients were given. This work was published very early; it was the first English work to call attention to Péclet's experiments, and is in a measure largely responsible for the coefficients which are used extensively by the English-speaking people.

Box and Péclet both present methods of computing building losses by applying the coefficients to small sections of the building. This method is an accurate one, but it seems to me, in view of the crudeness of the coefficients themselves, a refinement which is not warranted except for very large buildings. For

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that reason I advise the use of average values in computing the heat losses from walls and windows of buildings of ordinary or small size. My own opinion is that the average values, which can be readily and quickly applied, give fully as satisfactory results as the application of each special coefficient to each special part of the building, and it saves a great amount of labor. For large buildings the more exact method is preferable, as suggested by Box and Péclet.

From my study of the Péclet experiments, which I believe are the scientific basis of the coefficients practically used by all our authorities, I do not believe that they have such a degree of accuracy as to warrant extending our computation results very far. To illustrate, if the Péclet experiments involve an error of 10 per cent., which I think probable, it is rather absurd and foolish to carry our calculations in applying these coefficients to one-half of 1 per cent.; yet this is a thing which all of us are very prone to do, and we often imagine that because our figures are carried to small decimal places, our results are therefore very accurate.

The coefficients which are given by Recknagel and Rietschel agree so closely with those derived from Péclet's experiments, that I believe they have the same origin as those which we have obtained from Box, which we know came from Péclet. This fact confirms me in the opinion that the scientific derivation of the principal coefficients used for heat losses from buildings is derived from Péclet's experiments.

Respecting the coefficients for heat transmission from radiating surfaces, a large number of experiments have been made in nearly every country. The coefficients derived from these experiments, however, agree closely with those given by Péclet.

In view of the recent improvements in apparatus for measuring heat transfers and of the changes in building construction which have occurred during the last quarter century, it would certainly be desirable if the experiments made by Péclet could be repeated on a larger scale and with more accurate instruments. It is not probable, however, that if this were done the results would be essentially different from those obtained years ago by Péclet. We know that within certain practical limits Péclet's results are accurate, since the coefficients obtained from them when applied to modern heating systems give satisfactory

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results. In two cases I have had an opportunity of comparing the heat transmitted through the walls and windows of a building with the average of Péclet's results, and in both these cases the comparison checked up very closely.

In the first case a room on the second floor with exposed side and end had 246 square feet of wall surface and 96 square feet of window surface. By experiment I found that when the air in the room was 28 degrees above that outside, 4,247 British thermal units per hour were required to maintain a uniform temperature and represented the building losses; when 27 degrees above, 4,240 British thermal units were required. *The average of Péclet's results indicate that 4 square feet of wall surface or 1 square foot of window surface transmits practically 1 British thermal unit per square foot per hour per degree difference of temperature.* Applying this rule to the cases stated, the building loss for the first case should have been 4,410, and for the second case 4,253 British themal units.

In the second case a test of the New York State Veterinary College showed that to maintain the building 31 degrees warmer than the outside air, 16,000 British thermal units were required per minute, of which 39 per cent. escaped in the ventilation flues and 61 per cent. passed by conduction through the walls and windows. The building was exposed on all sides, was three stories in height, had 9,280 square feet of glass and 31,644 square feet of exposed wall surface. By the rule founded on Péclet's average results as above, the building loss should be 532,952 British thermal units per hour. The actual loss by experiment by the building was 547,200 British thermal units per hour, which is within 2 per cent. of that called for by the rule. In this case the building was of brick, thickness of walls 24 inches to 16 inches, the windows having single glass.

The above experiments, as well as those which are made on structures proportioned in accordance with the coefficients, indicate the substantial practical accuracy of the early experiments by Péclet, and show that we do not run any very great risk of making serious mistakes in applying them. It is quite probable that the variation in conditions as to materials or exposure, which are not considered in the average case, cause most of the errors in the application of these coefficients.

I am in hopes that this short paper will bring out for our

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Proceedings some additional information as to the origin of these coefficients and their probable accuracy in practice.

The following matter translated from Péclet will, I think, be of interest in this connection.

HEAT LOSSES THROUGH WALLS AND WINDOWS. FROM PÉCLET.

* The derivation of the formula for the loss of heat from the walls of buildings is given as follows by Péclet:

Let $M$ represent the quantity of heat that will traverse in a unit of time a plate with parallel faces, having an area of one superficial unit and a thickness represented by $e$. Let $t$ equal the temperature of the plate (not the adjacent air) on one surface and $t'$ the temperature on the other. Let $C$ equal the coefficient of conductivity. We have

$$M = \frac{C(t-t')}{e} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

If the body is formed of two plates in contact having a respective thickness of $e$ and $e'$ and coefficients of conductivities of $C$ and $C'$ with a temperature of $\theta$ for the faces in contact, we shall have

$$M = \frac{C(t-\theta)}{e}, \quad \text{also} \quad M = \frac{C'(\theta-t)}{e'},$$

from which, by eliminating $\theta$,

$$M = (t-t') : \left(\frac{e}{C} + \frac{e'}{C'}\right), \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

If there are a number of plates connected in the same way, we shall have in a similar manner

$$M = (t-t') : \left(\frac{e}{C} + \frac{e'}{C'} + \frac{e''}{C''} + \frac{e'''}{C'''}\right) \quad . \quad . \quad . \quad . \quad (3)$$

If the temperatures of the surfaces could be exactly known, it would be possible to calculate the amount of heat transmitted;

* Translated from *Traité de la Chaleur* by the author. From Carpenter's Heating and Ventilating of Buildings.

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but while it is possible to measure the temperature of the air in contact with the plates, it is not possible to measure the actual temperatures of the surfaces of the plates themselves.

Denote the temperature of the air inside an apartment by $T$ and that outside by $T'$. It is evident that heat will flow from the warm room to the cooler air outside, and that the inner surface of the wall will be cooler than the air of the room, and the outer surface will be warmer than the outside air. It will be possible to obtain three values of $M$ in terms of the coefficient of conductivity $C$, that of radiation $K$, and that of convection $K'$, since the amount of heat received by the inner surface is equal to that conducted through the wall and discharged from the outer surface. In forming these equations it is assumed that the heat transmitted is in every case proportional to the difference of temperature, which, although not quite exact, is sufficiently near for practical purposes, especially for small differences of temperatures. We have three equations as follows:

$$M = \frac{C(t-t')}{e}, \qquad M = (K+K')(T-t), \qquad M = (K+K')(t'-T').$$

By combining these equations substituting $Q = K + K'$, we have

$$t = \frac{T(C+Qe) + CT'}{2C+Qe}, \quad \ldots\ldots\ldots \quad (4)$$

$$t' = \frac{T'(C+Qe) + TC}{2C+Qe}, \quad \ldots\ldots\ldots \quad (5)$$

$$M = \frac{CQ(T-T')}{2C+Qe} \quad \ldots\ldots\ldots \quad (6)$$

If $Qe$ is relatively so small with reference to $2C$ that it may be neglected in the last formula, we have

$$M = \tfrac{1}{2}Q(T-T'), \quad \ldots\ldots\ldots \quad (7)$$

in which case the heat transmitted is independent both of the thickness of the material and its conductibility. As an example for a plate of glass several millimeters in thickness with a conductivity in metric measures as given in various tables:

$$C = 0.75, \qquad Q = K + K' = 2.91 + 2.20 = 5.10,$$

from which

$$2C + Qe = 1.50 + 5.10e.$$

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Taking $e$ equal to the following values, we have

| | | | | | |
|---|---|---|---|---|---|
| $e$ meters | 0.001 | 0.002 | 0.003 | 0.004 | 0.005 |
| $e$ inches | 0.04 | 0.08 | 0.12 | 0.16 | 0.2 |
| $2C + Qe$ | 1 5051 | 1.5102 | 1.5153 | 1.5204 | 1.5255 |

The above calculation indicates that within practical limits $2C + Qe$ remains constant, and that the heat transmitted through glass is independent of the thickness and coefficient of conductivity.

If, on the other hand, the coefficient of conductivity $C$ is very small and the thickness $e$ is very great, we can neglect $2C$ in the value of $M$, giving us as a consequence

$$M = \frac{CQ(T-T')}{Qe} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

As the value of $C$ is never less than $Q$ for any except the poorest conductors, such as half felt and filamentary bodies, it is necessary to have the thickness $e$ very great in order to have the conditions as above practically realized.

If there are two walls built in close contact and without air-space between them, with a temperature of $x$ at the junction surface and a thickness $e$, $e'$, coefficients of conductibility as before, we shall find several values of $M$ as follows:

$$M = \frac{C(t-x)}{e}, \quad M = \frac{C'(x-t')}{e'}, \quad M = Q(T-t), \quad M = Q(t'-T'),$$

from which can be obtained the following value of $M$ in terms of $T$ and $T'$:

$$M = \frac{Q(T-T')}{2+Q\left(\frac{e}{C}+\frac{e}{C'}\right)} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

If there are several walls in contact without an air-space between them, the value of the heat transmitted would be, with notation as before,

$$M = \frac{Q(T-T')}{2+Q\left(\frac{e}{C}+\frac{e'}{C'}+\frac{e''}{C''}\right)} \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

The foregoing computation, as stated by Péclet, applies to apartments in which the exposed walls are not opposite to each

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other, it being assumed that heat is radiated to an exposed wall by an inner unexposed wall of the same temperature as the room. For the condition where all the walls are exposed the temperature of each wall will be less than that of the room and there will be no reciprocal radiation. In considering this case mathematically we shall have to substitute in the last set of equations $K'$ the coefficient of convection for $Q = K + K'$, since in accordance with this hypothesis, $K$ becomes equal to 0. This hypothesis gives lower values than in the preceding case, as will be shown by example.

NOTE BY R. C. C.—There is little doubt but that the mathematical conclusion drawn by Péclet follows from the hypothesis adopted, viz., that all the radiant heat passing through the exposed walls must be reciprocally radiated from the interior walls. In most modern examples of heating, however, radiant heat is probably supplied the outside walls from furniture and heaters situated in the room to such an extent as to make the actual amount of heat transmitted practically as much in the one case as in the other, and in the tables already given the condition which gives the greatest transfer of heat only has been considered.

As explaining the use of the formulæ take the following example from Péclet. Assume a wall 10 meters (32.8 feet) in height formed of stone masonry, with coefficient of conductivity $C=1.7$ (slightly smaller than limestone). Coefficient of radiation $K = 3.60$ and coefficient of convection $K' = 1.96$ for a wall 10 meters high. Assume the interior temperature $T = 15°$ C. (59° F.) and the exterior temperature $T' = 6°$ C. (42.8° F.) as corresponding with mean conditions in Paris.

From this $Q = K + K = 3.60 + 1.96 = 5.56$. Substituting these various values in equations (4), (5), and (6), and assuming different values of the thickness ($e$) as follows, we have for a single exposed wall:

| Thickness ($e$) meters.... | 0.10 | 0.20 | 0.30 | 0.40 | 0.50 | 0.60 | 0.70 | 0.80 | 0.90 | 1.00 |
|---|---|---|---|---|---|---|---|---|---|---|
| " ($e$) inches .... | 3.9 | 7.9 | 12.8 | 15.7 | 19.7 | 23.6 | 27.6 | 31.5 | 35.4 | 39.4 |
| Temperature inside face of wall ($t$) deg. C..... | 11.15 | 11.6 | 12. | 12.3 | 12.56 | 12.77 | 12.96 | 13.1 | 13.2 | 13.3 |
| Temperature outside face of wall ($t'$) deg. C.... | 10. | 9.7 | 9.4 | 9.2 | 9.0 | 8.8 | 8.7 | 8.6 | 8.5 | 8.4 |
| Calories per square meter per hour, $M$..... | 25.4 | 22.3 | 19.8 | 17.9 | 16.2 | 15.0 | 13 8 | 12.8 | 12.0 | 11.2 |
| B. T. U. per sq. ft. per hr. | 9.3 | 8.2 | 7.4 | 6.6 | 5.9 | 5.5 | 5.1 | 4.7 | 4.4 | 4.1 |

For the case when all the walls are exposed we have:

| $t$ deg. C..... | 8.9 | 9.3 | 9.7 | 10. | 10.3 | 10.6 | 10.8 | 11.0 | 12.2 | 11.9 |
|---|---|---|---|---|---|---|---|---|---|---|
| $t'$ deg. C..... | 8.2 | 8.0 | 7.9 | 7.7 | 7.6 | 7.5 | 7.4 | 7.4 | 7.3 | 7.3 |
| Calories per square meter per hour, $M$..... | 12. | 11.1 | 10.4 | 9.7 | 9.1 | 8.6 | 8.2 | 7.8 | 7.4 | 7.0 |
| B. T. U. per sq. ft. per hr. | 4.4 | 4.1 | 3.8 | 3.6 | 3.3 | 3.1 | 3.0 | 2.8 | 2.7 | 2.6 |

For walls with air-spaces, having a temperature of $x$ and $x'$ at the respective sides of the air-space, we shall find without

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sensible error that the heat is transmitted through the space by radiation and convection, of which the coefficients are $K + K' = Q$. The heat transmitted through each space can be represented by $Q(x - x')$. The value of the heat transmitted will be expressed by substituting in equation (9) for $\frac{e}{C'}, \frac{e}{C} + \frac{1}{Q}$. Preserving the same notation, we shall have for walls with two air-spaces:

$$M = \frac{Q(T-T')}{2 + Q\left(\frac{e}{C} + \frac{1}{Q} + \frac{e'}{C'} + \frac{1}{Q} + \frac{e''}{C''}\right)} \quad . \quad . \quad . \quad (11)$$

If the walls are $n$ in number and each of the same material it follows that

$$M = \frac{Q(T-T')}{2 + \frac{nQe}{C} + n - 1} \quad . \quad . \quad . \quad . \quad . \quad . \quad (12)$$

If the construction consisted of several thin walls or parts without an air-space of the same total thickness as the wall with air-spaces as above, we should have $n - 1$ parts corresponding to the air-spaces and $n$ parts constituting the remaining part of the wall. By substituting in equation (12) the heat transmission will be for this case:

$$M' = \frac{Q(T-T')}{2 + n\frac{Qe}{C} + \frac{(n-1)Qe}{C}} = \frac{Q(T-T')}{2 + \frac{Qe}{C}(2n-1)} \quad . \quad . \quad (13)$$

By finding the ratio in the above equations Péclet proves that a wall with air-spaces 0.02 m. (0.8 inch) thick, as compared with the same wall with the spaces filled with baked clay, transmits the following proportion of heat:

| Number of walls or parts of walls..... | 2 | 3 | 4 | 5 | 10 |
|---|---|---|---|---|---|
| Proportion of heat transmitted in wall with air-space.. | 0.75 | 0.64 | 0.57 | 0.53 | 0.43 |

He shows that the thickness of the air-space should always be such that

$$e \text{ is less than } \frac{C}{K' + \frac{0.04}{e}}.$$

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The heat transmitted through the solid walls is by conduction, that through the air-space principally by radiation and convection, which latter quantity may under some conditions with thick spaces be so large as to overbalance the gain due to the air-space. This demonstration shows what has been found to be practically correct: that the less the radiation from the surfaces of the walls the more efficient will the air-spaces prove to be.

*Transmission of Heat through Glass.*—As already explained in connection with equation (7), the heat transmitted through glass when one side only is exposed to the air can practically be represented by the equation

$$M = \tfrac{1}{2}Q(T-T').$$

It also follows that if $x$ be the mean temperature of the glass,

$$M=(T-x)Q, \quad M=(x-T')Q, \quad \text{whence } x=\tfrac{1}{2}(T+T'). \quad . \quad (14)$$

When the entire enclosure is surrounded with glass Péclet states that the heat transmission will be somewhat less, because of the reduction in the temperature of the glass due to the lack of reciprocal radiation, and that the following equations apply:

$$M=(T-x)K', \qquad M=Q(x-T'),$$

from which we obtain

$$x=\frac{K'T+QT'}{Q+K'} \text{ and } M=\frac{QK'(T-T')}{Q+K'} \quad . \quad . \quad (15)$$

Péclet calculates the heat transmitted by the above formulæ with the following results:

| | | | | | |
|---|---|---|---|---|---|
| Height of windows, meters | 1 | 2 | 3 | 4 | 5 |
| " " " feet | 3.28 | 6.56 | 9.84 | 13.1 | 16.4 |
| Value of $K'$ (coefficient of convection), *one exposure* | 2.4 | 2.21 | 2.13 | 2.08 | 2.05 |
| Heat transmission per hour per degree C. per square meter, calories | 2.65 | 2.56 | 2.52 | 2.496 | 2.479 |
| Ditto per degree F. per square foot, B.T.U. | 0.98 | 0.945 | 0.93 | 0.92 | 0.91 |
| *Room surrounded with glass.* | | | | | |
| Heat transmitted per hour per degree C. per square meter, calories | 1.65 | 1.54 | 1.49 | 1.47 | 1.45 |
| Ditto per degree F. per square foot, B.T.U. | 0.608 | 0.568 | 0.55 | 0.542 | 0.535 |

NOTE.—It is quite probable that the hypothesis from which the equations are derived when the room is entirely surrounded with glass is erroneous for practical conditions.

By neglecting the thickness $e$ in the general formula it can be

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shown that the heat transmitted by multiple glass will bear the following proportion to that transmitted by a single thickness:

| Number of glass | 1 | 2 | 3 | 4 | $n$ |
|---|---|---|---|---|---|
| Proportion of heat transmitted | 1 | $\frac{2}{3}$ | $\frac{1}{2}$ | $\frac{2}{5}$ | $\frac{2}{1+n}$ |

The following tables of the coefficients for the thermal conductivity of poor conductors are taken from Péclet's work and are included here for reference.

CONDUCTION OF HEAT FOR ONE DEGREE DIFFERENCE OF TEMPERATURE PER HOUR.

| Material. | Per Degree Cent. | Per Degree Fahr. |
|---|---|---|
| | Per Square Meter 1 Meter Thick Calories. | Per Sq. Ft., 1 Inch Thick. B. T. U. |
| Gray marble, fine-grained | 3.48 | 28. |
| White marble, coarse-grained | 2.78 | 22.5 |
| Limestone, fine-grained (mean of three samples) | 1.82 | 14.8 |
| Limestone, coarse-grained (mean of two samples) | 1.3 | 10.5 |
| Plaster of Paris | 0.44 | 3.6 |
| Brick | .69 | 5.6 |
| Powdered brick, coarse-grained | .139 | 1.1 |
| Fir at right angles to the fibres | .093 | 0.75 |
| Fir parallel with fibres | .17 | 1.4 |
| Walnut at right angles to the fibres | .103 | 0.83 |
| Walnut parallel with fibres | .174 | 1.4 |
| Cork | .143 | 1.15 |
| Glass | .75 | 6. |
| Sand | .27 | 2.2 |
| Wood ashes | .06 | 0.5 |
| Powdered charcoal | .079 | 0.65 |
| Powdered coke | .160 | 1.3 |
| Cotton, raw or woven | .040 | 0.32 |
| Paper | .034 | 0.27 |

The following table for coefficient of convection K′ is taken from Péclet's work.

TABLE GIVING VALUES OF $K'$ FOR VARIOUS HEIGHTS IN METERS FOR A PLANE VERTICAL SURFACE.

| Heights, Meters. | $K'$. | Heights, Meters. | $K'$. |
|---|---|---|---|
| 0.10 | 3.848 | 2 | 2.21 |
| 0.20 | 3.186 | 3 | 2.13 |
| 0.30 | 2.926 | 4 | 2.08 |
| 0.40 | 2.770 | 5 | 2.05 |
| 0.50 | 2.66 | 10 | 1.96 |
| 0.60 | 2.585 | 15 | 1.92 |
| 1.00 | 2.400 | 20 | 1.90 |

NOTE.—The table shows a decrease in the coefficient of convection with increase in height in a vertical wall. This decrease is calculated from the hypothesis that the air which is heated rises while remaining in contact with the body, and for this reason has its capacity diminished for absorbing heat. This hypothesis is doubtless true in the case of absorption of heat by air-currents from radiators or heated bodies, but is probably considerably in error for walls of buildings, and may be entirely neutralized by the fact that the air against the interior wall is likely to be much warmer near the top, thus making an increasing temperature difference.

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*Heat Emitted from Hot Surfaces.*—The amount of heat given off by radiation and convection for various differences of temperature and from any surface when $K$ or $K'$ is unity

HEAT-UNITS PER HOUR.

| Radiation. | | | | | | Convection. | | | |
|---|---|---|---|---|---|---|---|---|---|
| Excess of Temperature. | | Total Radiation. | | Per Degree Difference. | | Total. | | Per Degree Difference. | |
| Deg. Cent. | Deg. Fahr. | Calories per Sq. Metre. | B. T. U. per Sq. Ft. | Calories per Sq. Metre. | B. T. U. per Sq. Ft. | Calories per. Sq.Metre | B. T. U. per Sq. Ft. | Calories per Sq. Metre. | B. T. U. per Sq. Ft. |
| 10 | 18 | 11.2 $K$ | 4.1 $K$ | 1.12 $K$ | .228 $K$ | 9.4 $K'$ | 3.4 $K'$ | 0.94 $K'$ | .189 $K'$ |
| 20 | 36 | 23.2 " | 8.6 " | 1.16 " | .239 " | 22.2 " | 8.2 " | 1.11 " | .228 " |
| 30 | 54 | 36.1 " | 13.2 " | 1.20 " | .243 " | 36.6 " | 13.5 " | 1.22 " | .045 " |
| 40 | 72 | 50.1 " | 18.5 " | 1.25 " | .257 " | 52.2 $K$ | 19.2 " | 1.30 " | .265 " |
| 50 | 90 | 65.3 " | 24.2 " | 1.31 " | .269 " | 68.6 " | 25.3 " | 1.37 " | .284 " |
| 60 | 108 | 81.7 " | 30.2 " | 1.36 " | .281 " | 86.0 " | 31.8 " | 1.43 " | .295 " |
| 70 | 126 | 99.3 " | 36.6 " | 1.42 " | .291 " | 104.0 " | 38.4 " | 1.49 " | .306 " |
| 80 | 144 | 118.5 " | 43.7 " | 1.48 " | .304 " | 122.6 " | 45.0 " | 1.53 " | .311 " |
| 90 | 162 | 138.7 " | 51.2 " | 1.54 " | .317 " | 141.7 " | 52.2 " | 1.57 " | .32 " |
| 100 | 180 | 161.3 " | 59.5 " | 1.61 " | .33 " | 161.5 " | 59.5 " | 1.61 " | .33 " |
| 110 | 198 | 185.3 " | 68.5 " | 1.69 " | .305 " | 181.5 " | 67.0 " | 1.64 " | .334 " |
| 120 | 216 | 211.3 " | 78.0 " | 1.76 " | .361 " | 202.1 " | 75.5 " | 1.68 " | .345 " |
| 130 | 234 | 239.3 " | 88.3 " | 1.83 " | .377 " | 223.1 " | 82.2 " | 1.72 " | .35 " |
| 140 | 252 | 269.5 " | 99.0 " | 1.92 " | .395 " | 244.4 " | 90.0 " | 1.74 " | .355 " |
| 150 | 270 | 302.1 " | 112 " | 2.01 " | .416 " | 266.1 " | 98.0 " | 1.76 " | .36 " |
| 160 | 288 | 339.0 " | 125 " | 2.12 " | .435 " | 288.1 " | 106 " | 1.79 " | .365 " |
| 170 | 306 | 371.4 " | 139 " | 2.22 " | .454 " | 310.5 " | 115 " | 1.82 " | .372 " |
| 180 | 324 | 418.5 " | 155 " | 2.32 " | .478 " | 333.2 " | 123 " | 1.85 " | .38 " |
| 190 | 342 | 463.2 " | 172 " | 2.43 " | .503 " | 356.1 " | 132 " | 1.87 " | .384 " |
| 200 | 360 | 511.2 " | 188 " | 2.55 " | .523 " | 379.4 " | 140 " | 1.89 " | .39 " |
| 210 | 378 | 563.1 " | 208 " | 2.68 " | .553 " | 402.9 " | 149 " | 1.91 " | .394 " |
| 220 | 396 | 619.0 " | 229 " | 2.81 " | .573 " | 426.7 " | 157 " | 1.93 " | .40 " |
| 230 | 414 | 679.5 " | 255 " | 2.95 " | .617 " | 450.4 " | 166 " | 1.95 " | .403 " |
| 240 | 432 | 744.8 " | 275 " | 3.10 " | .665 " | 475.0 " | 175 " | 1.97 " | .406 " |
| 250 | 450 | 848.7 " | 314 " | 3.39 " | .700 " | 498.6 " | 184 " | 1.99 " | .408 " |

FACTOR TO DETERMINE RADIATION LOSS FROM VARIOUS SURFACES.
VALUE OF COEFFICIENT $K$.

| | | | | | |
|---|---|---|---|---|---|
| Polished silver | 0.43 | Rusty sheet iron | 3.36 | Soot | 4.01 |
| Silvered paper | 0.42 | Cast iron, new | 3.17 | Building stone | 3.60 |
| Polished brass | 0.258 | Rusty cast iron | 3.36 | Plaster | 3.60 |
| Gilded paper | 0.23 | Glass | 2.91 | Wood | 3.60 |
| Red copper | 0.16 | Powdered chalk | 3.32 | Calico | 3.65 |
| Zinc | 0.24 | " wood | 3.53 | Woollens | 3.68 |
| Tin | 0.215 | " charcoal | 3.42 | Silk | 3.71 |
| Polished sheet iron | 0.45 | Fine sand | 3.62 | Water | 5.31 |
| Sheet lead | 0.65 | Oil painting | 3.71 | Oil | 7.24 |
| Ordinary sheet iron | 2.77 | Paper | 3.71 | | |

NOTE.—To find the total heat emitted by radiation, multiply the value of $K$ as given in the above table by the numbers corresponding to radiation due to difference of temperature as in the preceding table.

is given in the above table, as computed from Péclet's experiments. The total heat emitted by any surface will be obtained by multiplying the results given in the first table by the factor of radiation and convection for the required conditions. This table is exact for the surrounding air at 15 degrees Centigrade or 59 degrees Fahrenheit.

The following table gives the total loss from various forms

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of direct radiating surfaces in still air, calculated by Péclet's coefficients, slightly modified by recent experiments.

HEAT-UNITS EMITTED PER HOUR PER SQUARE FOOT FROM VARIOUS SURFACES, DIRECT RADIATION, STILL AIR.

| Difference of Temperature. | Coefficient or Amount per Degree Difference of Temperature. | | | | Total per Square Foot per Hour.* | | | |
|---|---|---|---|---|---|---|---|---|
| | Horizontal Pipe, Diameter. | | | | Horizontal Pipe, Diameter. | | | |
| | 6 in. | 4 in. | 2 in. | 1 in. | 6 in. | 4 in. | 2 in. | 1 in. |
| | Radiator, Height. | | | | Radiator, Height. | | | |
| Deg. F. | 40 in. Massed Surface. | 40 in. Thin. | 24 in. Massed. | 12 in. Thin. | 40 in. Massed Surface. | 40 in. Thin. | 24 in. Massed. | 12 in. Thin. |
| 10 | 0.55 | 0.62 | 0.66 | 0.85 | 5.50 | 6.7 | 6.6 | 8.5 |
| 20 | 1.11 | 1.25 | 1.32 | 1.72 | 20.2 | 24.9 | 26.4 | 34.4 |
| 30 | 1.18 | 1.34 | 1.42 | 1.84 | 35 | 39.7 | 42.7 | 55.2 |
| 40 | 1.24 | 1.40 | 1.48 | 1.92 | 49.6 | 56.2 | 59.0 | 77 |
| 50 | 1.29 | 1.46 | 1.54 | 2.01 | 64.5 | 73.0 | 77 | 100 |
| 60 | 1.33 | 1.50 | 1.58 | 2 06 | 79.8 | 90 | 95 | 124 |
| 70 | 1.36 | 1.54 | 1.63 | 2.12 | 95.2 | 108 | 113 | 148 |
| 80 | 1.40 | 1.58 | 1.67 | 2.18 | 112 | 127 | 133 | 173 |
| 90 | 1.43 | 1.63 | 1.72 | 2.24 | 128 | 147 | 153 | 199 |
| 100 | 1.47 | 1.66 | 1.76 | 2.28 | 147 | 167 | 175 | 228 |
| 110 | 1.51 | 1.71 | 1.80 | 2.34 | 166 | 188 | 198 | 257 |
| 120 | 1.54 | 1.74 | 1.84 | 2.39 | 184 | 208 | 219 | 287 |
| 130 | 1.57 | 1.78 | 1.88 | 2.44 | 203 | 230 | 242 | 318 |
| 140 | 1.61 | 1.81 | 1.91 | 2.48 | 223 | 252 | 266 | 346 |
| 150 | 1.64 | 1.84 | 1.94 | 2.53 | 244 | 276 | 291 | 378 |
| 160 | 1.66 | 1.87 | 1.97 | 2.57 | 265 | 300 | 316 | 410 |
| 170 | 1.69 | 1.91 | 2.02 | 2.62 | 286 | 324 | 341 | 443 |
| 180 | 1.72 | 1.94 | 2.05 | 2.65 | 307 | 348 | 367 | 475 |
| 190 | 1.75 | 1.98 | 2.09 | 2.71 | 330 | 375 | 393 | 512 |
| 200 | 1.78 | 2.01 | 2.12 | 2.76 | 356 | 403 | 415 | 552 |
| 225 | 1.87 | 2.12 | 2.24 | 2.91 | 420 | 477 | 500 | 650 |
| 250 | 1.97 | 2.23 | 2.35 | 3.06 | 493 | 557 | 587 | 762 |
| 275 | 2.07 | 2.34 | 2.47 | 3.22 | 563 | 637 | 670 | 872 |
| 300 | 2.17 | 2.45 | 2.58 | 3.37 | 654 | 712 | 780 | 1020 |
| 325 | 2.27 | 2.55 | 2.70 | 3.50 | 740 | 840 | 882 | 1150 |
| 350 | 2.37 | 2.67 | 2.82 | 3.66 | 835 | 945 | 995 | 1295 |

* Results divided by 1000 give approximate weight of steam condensed per hour.

FACTOR TO DETERMINE CONVECTION LOSS FROM BODIES OF VARIOUS DIMENSIONS.

Value of Coefficient $K'$.

| Diameter. | | Sphere. | Horizontal Cylinder. | Vertical Cylinder, Height in Metres and Feet. | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Metres. | Inches. | | | 0.5 m. 1.64 ft. | 1 m. 3.28 ft. | $h$ 2 m. 6.56 ft. | $h$ 3 m. 9.84 ft. | $h$ 4 m. 13.12 ft. | $h$ 5 m. 16.4 ft. | $h$ 10 m. 32.8 ft. |
| 0.025 | 0.984 | ..... | 5.114 | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 0.05 | 1.968 | 6.9 | 3.59 | 3.55 | 3.2 | 2.95 | 2.84 | 2.79 | 2.73 | 2.62 |
| 0.10 | 3.94 | 4.38 | 2.82 | 3.22 | 2.9 | 2.68 | 2.57 | 2.52 | 2.48 | 2.38 |
| 0.20 | 7.88 | 3.08 | 2.44 | 3.05 | 2.75 | 2.54 | 2.44 | 2.39 | 2.35 | 2.26 |
| 0.40 | 15.74 | 2.43 | 2.25 | 2.93 | 2.65 | 2.45 | 2.35 | 2.30 | 2.26 | 2.17 |
| 0.60 | 23.62 | ..... | 2.18 | 2.88 | 2.60 | 2.40 | 2.31 | 2.26 | 2.22 | 2.13 |
| 0.8 | 31.50 | 2.10 | 2.15 | 2.85 | 2.57 | 2.37 | 2.28 | 2.23 | 2.20 | 2.11 |
| 0.10 | 39.38 | ..... | ..... | 2.83 | 2.55 | 2.36 | 2.26 | 2.22 | 2.18 | 2.09 |
| 0.16 | 63.0 | 1.94 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | | | ratio $\frac{l}{d}$ | 20 | 20 | 20 | 15 | 13½ | 12.5 | 20 |

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## CLXXIV.

# COMPARISON OF QUICK CIRCULATING SYSTEMS OF HOT-WATER HEATING.

BY C. GUITTON, ST. ETIENNE, FRANCE.

(Non-member of the Society.)

Presented by Request.

The system which was described by the inventor, A. B. Reck, at a meeting of the American Society of Heating and Ventilating Engineers (Transactions Vol. X., 1904), is the prototype of all systems in which the water in a closed circuit is mixed with steam (Brückner, Hamelle, Kœrting, etc.).

Its principal feature is the double action of the steam upon the ascending column of a thermo-siphon with closed tank. One, the ordinary feature, is to heat the lower part of the column. The other, the new feature, is that a certain amount of steam rises to the upper part of the pipe and is there mixed with water, forming an emulsion or mixture of low specific gravity.

For this purpose, a steam generator is used in Reck's system, more complicated certainly than a water boiler, but also more efficacious by reason of its arrangements for regulating the fire and the pressure of steam. An apparatus, called a reheater, through which flow both the water from the boiler and the steam from the generator, raises the temperature of the main rising pipe, without causing the water in it to boil. Another apparatus, called a circulator, probably from the fact that it is the chief factor in inducing circulation, is fixed at a certain height on the rising pipe; a certain amount of steam from the generator is allowed to penetrate into this apparatus and mixes in the form of steam bubbles with the water from the rising pipe.

All the systems derived from the above, such as Brückner's, Hamelle's, Kœrting's, etc., make use of a simple water boiler to obtain this double action, the body of the boiler forming the

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lower part of the ascending column, as in the case of an ordinary thermo-siphon. At a certain height on this column a steam space is arranged into which the steam from the heated water in the boiler gathers. In this steam space is an arrangement of varying shape, which serves to split up more or less the steam penetrating into the water, after the fashion of an injector. In these systems, the boiler acts as reheater and the steam space as circulator. There are two particularities in this method of installation: the water heater becomes a boiler, as it has to produce steam, and the injector, with its constant and even flow, has to discharge all the steam issuing from the boiler. It differs from Reck's system, in that the rising water boils before arriving at the mixing point, and because there is no fixed mixing proportion.

In all the systems, whether Reck's or derived therefrom, the current of hot water, which is saturated with steam as soon as the injector begins to operate, rises directly upwards to a closed expansion tank: the two fluids will there separate freely; the water, being heavier, will remain at the bottom of the tank and will descend through the hot water main, while the steam rising to the top of the tank passes through a pipe to a condenser. The use of the condenser is twofold: first it lowers the pressure of the steam which might otherwise set up counter pressure in the rising main, and secondly it returns the condensed steam to the boiler. The essential qualification of a regular circulation being its power of absorption, this must be kept in perfect order so as to ensure a regular condensation.

In Reck's system the condenser is cooled by the water from the rising column passing through it at a point where the water is not yet boiling, to say below the mixer. In the derived systems, the apparatus is cooled in different ways: Brückner—by spraying the steam into the return water; Hamelle—by means of a dome placed above the expansion tank and well exposed to the action of the air; Kœrting—by means of the cooling action of the water in the descending pipe. These different positions of the condenser in the systems derived from Reck's are necessitated by the water boilers which are used, and which, as stated before, superheat the water in the lowest part of the rising pipe.

In spite of these differences, all the circulations, Reck, Brückner, Hamelle, Kœrting, etc., are based on the same principle and have the same end in view.

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If we omit their condensers, which are of secondary interest, they can all be represented concisely as in Fig. 1.

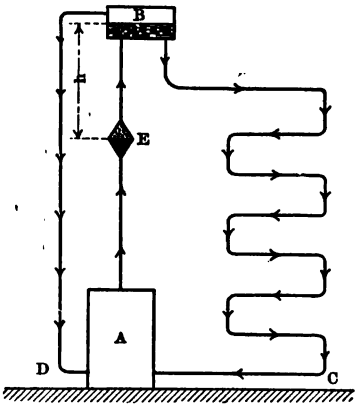


FIG. 1.

*A* is the source of heat, a steam boiler having a reheater over it, or a water boiler;

*B*, the closed expansion and separation tank;

*AB*, the ascending column, heated at its lower part *A* and mixed with steam in its upper part *E*;

*BC*, the descending column or heat distributor;

*BD*, the special piping for reducing the pressure of the steam when it reaches *B*, and for returning the condensation to the boiler;

*E*, the mixing point, either with steam coming from outside the rising column or from a space arranged on the column.

This sketch shows that the flow of the water, *ABC*, is accelerated in proportion to the difference of density in *AB* and *BC*. It is clear that assuming the specific weight of the water to be 1, this difference will be at its maximum if these densities are 0 in the rising column *AB* and 1 in the distributing pipe *BC*.

But such a difference is impossible, whatever be the height of the part containing the mixture, *h*, on the column *AB*. To bring that about there would have to be no water at all in the ascending column, and only water at 4°C. (39° Fahr.) in the pipe feeding the heating surfaces. It would be impossible to get anywhere near such a difference. For, if the average density of the column *BC* can be kept very near to unity, to say 0.98 for instance, the specific weight of the emulsion depends upon two factors, a

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minimum of water and a maximum of steam, both of which cannot be overstepped. The minimum is the water which should pass through the heating surfaces to ensure the desired emission of heat from them. The maximum is the steam which can positively be condensed by the water itself in the circuit.

This difference in density of the two columns is still further decreased by the rather low temperature at which it is proper to introduce the steam in the rising pipe, the lowest temperature depending upon the heat units which can be given off in the circuit without causing a local boiling. In effect, the result of this boiling would be a counter-pressure to the rising force of the emulsion. An example will show clearly the importance of this condition: Let us suppose that the temperature of the steam gives an emulsion at 120° C. (248° Fahr.). If the pressure in the separating tank is very slightly in excess of the atmospheric pressure, each liter of the emulsion will give off therein 120 — 100 = 20 calories (79.2 British thermal units). Let us suppose, on the other hand, that the water of the ascending or descending column, which acts upon the condenser, has a temperature of 85° C. (185° Fahr.). A liter of this water can only absorb 100 — 85 = 15 calories (59.4 British thermal units), otherwise it would reach the boiling point. Now, the 15 calories absorbed only represent three-quarters of the 20 calories to be reduced, and the difference unabsorbed would set up counter-pressure.

To avoid this excess, Mr. Reck sets a limit to the height of the separating tank above the circulator (page 75, Vol. X). For, the greater the water pressure on the injector, the higher must the steam pressure be raised, that is, its temperature, in order to equalize this pressure. Otherwise the steam would not be able to penetrate into the pipe. According to Mr. Reck (pages 59 and 73) the proper height is that which limits the specific gravity of the part mixed to one-half of that of the descending column of the same height. This difference of one-half of the specific gravities would ensure a velocity in the circulation, of 14 or 15 inches per second, or 0.35 to 0.375 meters per second (page 74), in pipes of ¾ in. and ½ in., or 20 mm. and 15 mm., such as are generally used.

From these data as well as from the preceding considerations, we can conclude that there is a normal limit to this difference of

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specific gravities and that this limit, one-half, is the normal motive power in Reck's circulation.

It is not probable that other systems of mixed circulations would increase this particular force. If a water boiler forming an integral part of the circuit is substituted in place of a steam boiler acting parallel to the circuit, the pressure regulating devices would have to be placed considerably further off, thus causing their working to be more imperfect and less easily controlled. The safety valve is put on the highest point of the circuit, and the pressure regulator must be acted upon by the steam from the separating tank. Further, as the injection can be no longer regulated, it depends upon the tension of the steam accumulated in the ascending column, and which is often immoderately high. This pressure may become so great as to drive back the water from the boiler, even partially emptying the latter. This phenomenon, which happens accidentally in thermo-siphons with open tanks, becomes in this case quite natural, because the water in the boiler is usually close to the boiling point. Finally, the reheating of the descending column results in the decrease of the specific gravity of this column and of thus opposing a resistance to the upward (ascending) force. For these reasons, it is believed that the difference of specific gravities, which usually takes place in the circulations derived from the system, should not be greater than that of the system itself.

We therefore give a résumé of the generic characters of all these circulations:

I. They are based upon the partial emulsion, by steam injection, of a closed water circulation; the pressure of which, constantly tending to increase on account of the steam acting in a closed tank, must be regulated by safety devices such as are used for steam generators.

II. The motive force obtained under these conditions of emulsion and regulation is represented by the difference between the densities of the two columns, of the respective values of 2 and 1, thus $2 - 1 = 1$.

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## ROUGUAUD'S CIRCULATION, OR CIRCULATION "BY FALL."

This system is very different from emulsioned circulations. Specific weight plays no part in it. It resembles steam heating "à air libre," in which the water of the distributor falls by its own weight into an open tank, before entering the boiler where it is to obtain a new supply of heat for a fresh effort. There is this difference, however, that the water rises not in steam but in the form of a boiling fluid.

This circulation comprises three phases: the flow of hot water in the distributor, the flow of the cooled water to the boiler, which is provided with a special elevator or water-lifter, and the raising of the boiling water to its highest point. These phases are shown in Figure 2 by single, double and triple arrows.

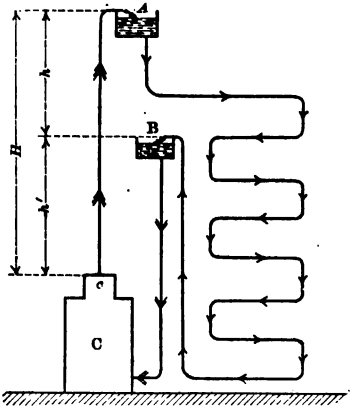


FIG. 2.

*A* is the topmost reservoir, or overflow tank;

*B*, lower tank, or collector;

*C*, water boiler with elevator *c*, either inside or outside the boiler.

The distribution through the circuit is brought about by hot water, at 100° C. (212° Fahr.), falling freely from the upper reservoir or open tank *A*, to the lower open tank *B*, in accordance with the natural laws of gravity governing bodies falling through space. The motive power is not caused by a difference in density but a difference in levels, the height of the drop *h*.

The water is returned to the raiser through the boiler by an-

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other drop, from the lower tank *B* to the chamber of the elevator *c*, which communicates with the air by a large-sized pipe *cA*. The motive power of this flow is again a difference in levels, the height *h'*.

The rise of the boiling water, from *c* to *A*, is assured by means of an improved hydraulic valve, whose work it is to keep the steam tension in *c* equal to the static pressure of the column *cA*. This tension can never exceed this static pressure, for as soon as the tension simply equals the pressure of the column, the hydraulic valve causes the water in the pipe *cA* to flow out into the tank *A*, and then the steam space is placed in direct communication with the air. The motive force for this discharge of water is again equal to a difference of levels, *i. e.*, the height *H*, being the sum of *h* plus *h'*.

Consequently every part of the circulation is governed by a static pressure exclusively.

We see from these three phases that the current falling in a cascade from the upper tank, through the lower tank, to the elevator chamber, may be either constant or intermittent. Constant, if the quantity of the three discharges are equal for the same time unit. Intermittent, if one should not balance the two others.

It is less easy in practice than in theory to equalize these three discharges. Besides, as the object of the heating installation is to accumulate in the distributing circuit a certain quantity of calories per hour, it is not indispensable to have a continuous current. Therefore a regularly recurring current has been adopted.

In order to ensure this regular recurrence, we must calculate what discharge must be furnished by the elevator per hour, and arrange for its intermittence in such a way that the greatest frequency in the elevations shall correspond with a maximum of cold. The practical rule given for attaining this maximum is easy to observe and has been sanctioned by five years' experience in heating work. It gives a time limit of 60 seconds for the fall of a certain quantity of hot water through the circuit, and a slightly shorter time limit, say 50 seconds, for an equal quantity of cooled water to pass from the lower tank to the upper tank, with the aid of the elevator. The margin of 10 seconds between these two flows simultaneous represents the minimum interval between the falls at their greatest frequency, or an instant of rest. This instant makes the dividing line between the two flows forming the

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parallel transport, that is, the filling up of the elevator through the boiler and the ascension of the boiling water. The time generally taken for these two flows is respectively 20 and 30 seconds, or a total of 50 seconds.

This rule establishes the proportion of the heights $h$ and $h'$ to the height $H$ for given diameters of piping and, consequently, the velocity of the three currents. These velocities are generally 0.50 to 0.75 *m.* (20 to 27½ inches) per second for the fall in the distributing mains, and from 1 *m.* to 1.40 *m.* (40 to 55 inches), for the fall into the elevating chamber. These two velocities are independent of each other, and they are also each independent of the velocity of ascension, which is usually limited to 0.50 *m.* (20 inches). On account of these velocities being independent, it is possible to take very small diameters for the distributing piping, such as ¾ in. (20 mm.), ½ in. (15 mm.) and even less, and to place the piping of larger diameter near or above the boiler.

It should be remembered that there is an instant of rest allowed for between two series of flows. The interval of rest at the point of greatest frequency of these series is 10 seconds between the two falls in the distributing piping, and 40 seconds between two falls in the elevator.

The velocities per second of the two falls cannot therefore correspond to the velocities per hour, as is the case with the continuous currents. The amounts they discharge per hour are, in fact, identical with what would be obtained with lower continuous velocities of $\frac{10 \times 60}{3600} = \frac{1}{6}$ for the first flow, and $\frac{40 \times 60}{3600} = \frac{2}{3}$ for the second. They must therefore be returned to their effective value per hour, by subtracting respectively $\frac{1}{6}$ part and $\frac{2}{3}$. If we take their averages, $\frac{0.50 + 0.70}{2} = 0.60 m.$ (23.6 inches) and $\frac{1 + 1.40 m.}{2} = 1.20$ *m.* (47 inches), and make the reductions, the mean practical velocities are still 0.50 *m.* $\left(\frac{0.6 + 5}{6}\right)$ for the first fall, and 0.40 *m.* $\left(\frac{1.20 + 1}{3}\right)$ for the other one.

In this study of the circulation, there is no necessity to go into

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details as to the use of the steam given off by the water supplied by the elevator, at a temperature in proportion to the height *H*. Even if it were of no utility it would have no influence on the circulation. It is enough to point out that this steam is, as in every well devised installation, undergoing total recuperation, both as regards latent heat and water of condensation. It is taken up again by various apparatus for the benefit of the circulation or its exterior service, according to the rules regulating its escape to the open air and without inducing counter-pressure.

The natural limit of the periodic circulation properly arranged is continuous circulation. It becomes continuous as soon as the heating power of the boiler is greater than the requirements of the circuit, whether maximum or temporary. This creates no difficulties. But it is not used on account of its action being less powerful and less efficient. Consequently, the transmission of heat from the boiler is limited by means of a double fuel regulation, one being regular, the other optional. The former is fixed once for all to suit the maximum of cold to be overcome. The latter varies according to the season or to suit individual requirements.

Should the heating power thus determined be excessive, the return flow of water, generally assumed to be at a temperature of 70° to 80°C. (158° to 176° Fahr.), will arrive in the boiler too hot, and will partly vaporize there before reaching the elevator, thus causing an excess of steam pressure in the box of the hydraulic valve. The consequence of this excess would be to modify the working of this apparatus and make it act as an injector. The ascending water becomes saturated with steam, as in the mixed circulations, and rises continuously. Then its current is maintained by means of a steam tension which balances the static pressure $h'$ of the lower tank above the elevator chamber. However great may be this static pressure, the steam cannot take up more room than the capacity of the hydraulic valve-box, because the precise characteristic of this device is to set up direct communication between the steam and the outside air as soon as it attains this volume. Consequently the steam can never expand in the water boiler, as often happens with the thermo-siphon.

As soon as the heating power of the boiler is again brought down to the requirements of the circulation, either from the fire having been moderated on purpose or naturally, or by the cooling

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of the return water, the water returning to the boiler no longer gives off steam, the excess of steam disappears in the elevator chamber, and continuous circulation again gives way to periodic circulation.

Both in the continuous and periodic circulation, the motive force of the circulation is a pressure solely static.

The leading features of this system may be thus resumed:

I. It is based upon the periodic or continuous fall of water from open tank into open tank, through open circuits, and the pressure being solely static, there is no need for the use of any safety device.

II. The motive force of the circulation in the heating circuit may be represented by the difference between two columns of the respective values of 2 and 0, thus $2 - 0 = 2$.

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## CLXXV.

# HEATING SYSTEMS FOR RAILWAY CARS.

BY R. C. CARPENTER.
(Member of the Society.)

The heating of railway cars is a subject which has not received attention in the various meetings of this Society. I do not propose in the present paper to criticise any of the present methods which are in use or suggest improvements, no matter how badly they may be needed, but will give a short sketch in a general way of the various systems which have been and are in use for heating railway cars, with the hope that it will lead to a discussion which will bring out many structural details and matters of importance which should be preserved in the records of our Society.

The American railway coach for passenger service is generally a long structure consisting of a single room mounted on wheels; its dimensions varying in length from 60 to 70 feet, its width from 8 to 9.5 feet and its height varying from 6 to 9 feet. The coach must be amply supplied with windows, and its structure is generally such as to expose a great deal of radiating and conducting surface, both of glass and thin wall, and the motion of the car through the air produces the same effect in removing the heat as a strong wind striking against a stationary structure. The conditions relating to its use are essentially different from those relating to fixed habitations; the system of construction employed in its erection is different from that of houses, and as a consequence the coefficients which must be employed in computing the amount of radiating surface are likely to be different from those we are accustomed to use in proportioning the radiating surfaces in fixed structures.

### *Heating with Stoves.*

Previous to 1870 the passenger cars were quite generally warmed by stoves, one of which was located at each end of the

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car. These stoves were generally of a special pattern and designed with doors that were supposed to remain closed, even if the car should be overturned, but as a matter of fact they did not do so, and the stoves proved both inefficient and dangerous in car heating.

### *Hot-water Heating.*

The inefficient results in the distribution of heat in various portions of the cars led very early to the design of a heating system with an extended radiating surface which would transfer the heat equally to all portions of the car. The system which met with the most success for distributing the heat employed hot water, and was patented by William C. Baker, March 10, 1868. This system was extensively used, and at date of 1880 was in almost universal use for the purpose of heating railway cars.

The Baker hot-water heating system differs materially from that employed in the heating of buildings in the arrangement of the heating surface with respect to the furnace and in its general mode of operation. The Baker hot-water heater of necessity had its grate and heating surface on a higher level than the radiating surface in the car, this being necessary because the radiating surface, in order to be out of the way and be efficient, must be arranged close to the floor. This practically cuts off all opportunity for obtaining a head for producing gravity circulation such as we obtain in stationary structures by the arrangement of the radiating surface some distance vertically above the heating surface in the heater. This will be evident from an examination of Figs. 1 and 2, which give the plan and elevation of the

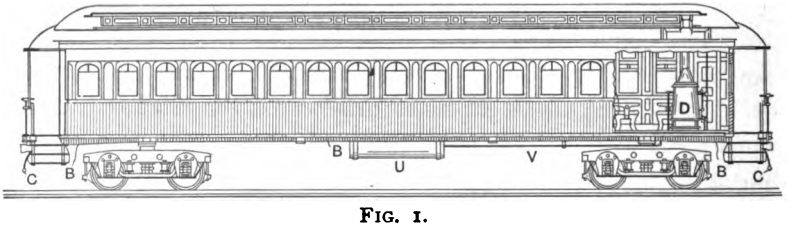


FIG. 1.

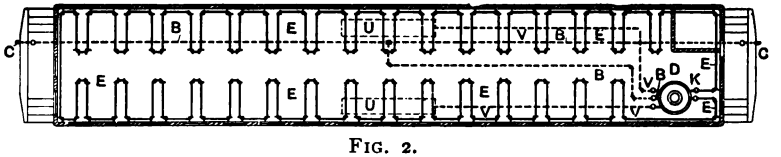


FIG. 2.

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Baker hot-water system as applied to a car. An examination of the drawing shows the hot-water heater located at *D* and the piping arranged to extent under every seat. The system is better shown in Fig. 3, which is reproduced from the Baker patent.

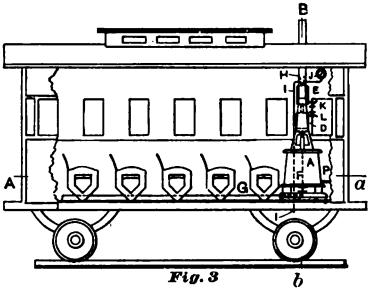


*Fig. 3*

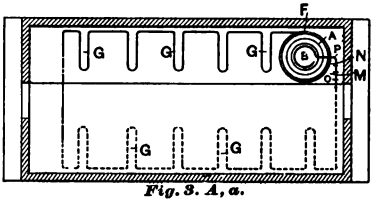


*Fig. 3. A, a.*

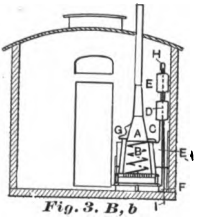


*Fig. 3. B, b*

The heater *A* consists of a coil *B* arranged so that the cooler water enters at the bottom, and the heated water and steam are discharged from the top through the pipe *C*. In the structure shown in the patent the flow takes place into a reservoir, *D*, which is connected by a pipe with an expansion chamber, *E*, which latter is provided with a safety valve, *H*, which opens in case of an excess of pressure. From the reservoir, *D*, the downward circulation takes place through the pipe, *F*, into the radiating surface, *G*, which latter is partly on one side of the car and partly on the other. The whole radiating surface, as shown, is a single pipe construction through which the entire water in the system must circulate. A gauge for showing the pressure was applied to the system and also cocks for filling and draining.

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In practice the system was somewhat modified, the closed expansion tank being located above the roof of the car in any position where the accidental discharge would not fall into the car. The lower reservoir was reduced to a fitting which connected the flow and return pipes together, but in all essential matters the structure employed was essentially that which is shown in the Baker patent, Fig. 3, although in practice the proportions were much modified.

A consideration of this structure serves to show that there is absolutely no gravity circulating head, and no force which will cause circulation to exist throughout the system due to the different weights in the ascending and descending columns; on the contrary, a calculation will show that there is apparently a tendency, so far as producing circulation by gravity is concerned, for the water to move downward through the heater rather than in the proper direction.

This fact was fully pointed out in a paper before the Western Railway Club of Chicago, in May, 1895, by James F. McElroy, consulting engineer for the Consolidated Car Heating System. It is a well-known fact, however, that the Baker hot-water system did successfully maintain a circulation in the reverse direction from that which would be produced by gravity, which was due to the formation of steam bubbles in the coil and heater and to the elastic force of the steam generated. The steam bubbles reduced the weight in the ascending column, passing through the heater, and also tended to act by their elastic force, thus causing a positive and rapid circulation. The circulation due to this cause is of an intermittent nature due to the alternate formation and condensation of the bubbles, the circulation produced, however, is positive and the force exerted in the formation of bubbles is sufficient to make an effective circulation, even though the radiating surface is below that of the heating surface in the heater.

### *Hot-water Systems Heated by Steam.*

The Baker system of hot-water heating was successful so far as the distribution of heat to the various portions of the car is concerned, but it was open to the serious objection of requiring an open fire in each and every car of the train. To satisfactorily

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care for these various fires required much labor, and the passengers were subject to considerable inconvenience from the dust from the coal and the work of attending the fire, which work was often very inefficiently done. The principal objection, however, was the added danger in case of an accident, due to the numerous open fires on the train, which was especially emphasized by the accidents at Angola, 1867; at Revere, 1871; Prospect, 1872; Richmond Switch, 1873, and Ashtabula, in 1876, where the fire from the heaters greatly increased and aggravated the horrors due to the railway accidents.

These accidents called public attention to the dangers of keeping open fires in railroad cars, and led to a public demand for a system of heating with steam from the locomotive. In some States laws were passed requiring all trains to be heated after a certain time in this manner.

As the cars were generally equipped with the Baker hot-water heating system, nearly all of the first successful installations embodied the use of steam as a primary source of heat to warm the hot water in the Baker heating system. This system also presented the advantage of affording means for warming the car in case it were detached from the train by maintaining a fire in the Baker heater, which latter was and is a matter of considerable practical importance.

About 1880 numerous patents were taken out for warming the water in the various hot-water heater systems of the cars by steam taken from the locomotive. The problems involved in this case which were new, and had to be practically solved before the systems could operate successfully, were, first, the development of a coupler for connecting the various cars which made up a train which of necessity should have the features of flexibility, tightness, strength, interchangeability and facility of coupling and uncoupling. The production of a suitable coupler was a problem which required considerable time to work out, the difficulties being much increased by the fact that the cars were interchanged from one railroad system to another, which practice made necessary a standard form throughout the country to meet the demands of interchangeability.

The Sewall, Gold and Westinghouse couplers proved successful, and were extensively used on different systems. At the present time the Gold coupler is the one almost universally used.

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The cut, Fig. 4, shows the forms of most of the successful couplers which have been used in the heating of railway cars. An

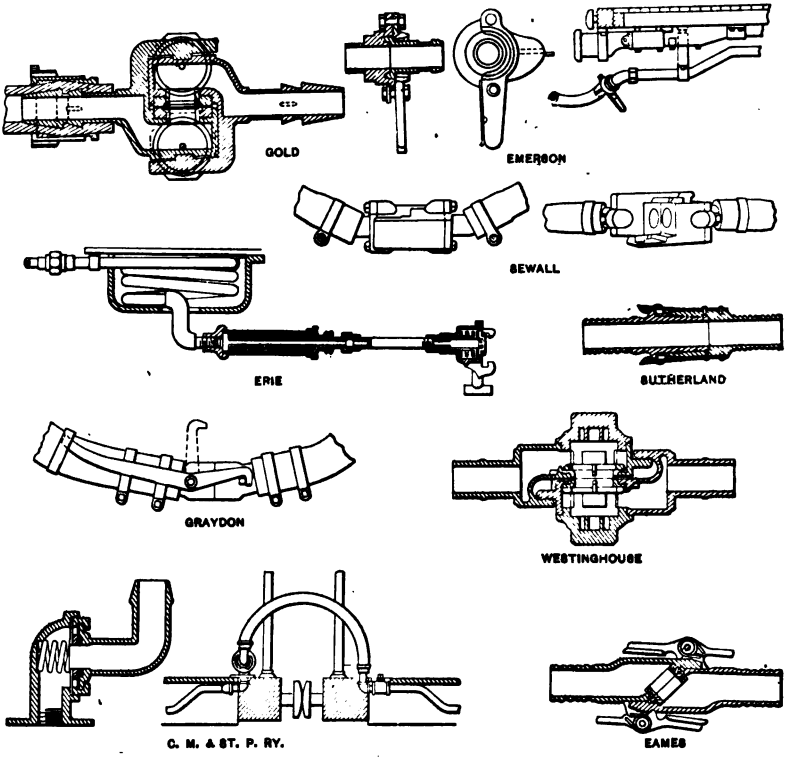


FIG. 4.—HOSE COUPLINGS FOR RAILWAY CARS.

experience in heating railroad cars led to the use of flexible hose of short length for connecting the steam pipe of one car with that of the adjacent car.

The second problem of importance which needed to be solved was that of producing circulation in the hot-water heating system of each individual car effectively and noiselessly with the steam from the locomotive, substituted for the fire in the Baker stove. In order to solve the problem of circulation, numerous inventions were brought forward which generally related to the location of the steam heater with reference to the circulating pipes of the hot-water heating system. It was generally required that the heating system should be applicable to the Baker fire-heating system, which latter was to be maintained in condition for use when steam from the locomotive was not available. An

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interior view of a car with three steam heaters and an auxiliary stove heater is shown in Fig. 5, as equipped by the Consolidated Car Heating Company in 1892.

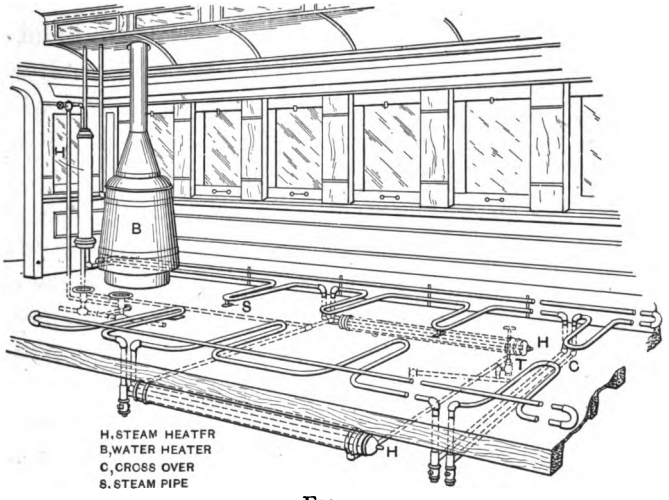


FIG. 5.

The records of the United States Patent Office show numerous schemes for heating the water in the Baker hot-water system with steam taken from the locomotive. These patents show various forms of steam heaters, in some of which the water circulated in a coil through the steam drum, but the preferred form was generally that in which the steam circulated in a coil through the surrounding body of hot water in a drum. In one successful form of heater the steam was contained in a series of disks connected together, which was surrounded by the hot water to be warmed. The steam pipes were in all cases provided with a drip for removing the water of condensation; various schemes were proposed for controlling the discharge from this drip, and traps of various forms, as well as plain orifices regulated by hand, were shown and employed. A successful device of this character appears to have been a plain orifice controlled by a valve regulated by hand, which was steam jacketed so as to prevent freezing of the discharge in extremely cold weather, although a thermostatic steam trap is extensively employed.

The character of attendance on railroad trains has never been such as to render delicate automatic devices reliable. It has been proved from experience that better results were obtained usually

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when the care of the heating apparatus, such as the turning on of the heat or the draining of the heating pipes, was made a part of the simple routine duties of the attendant, who on the American railroads has the position of "brakeman." It may be remarked here that the steam trap in use for draining the steam heater on the railroads is likely to be disarranged and give poor service, because of the varying pressures of steam likely to come upon it and of the jarring incidental to its position on the car.

The hot-water heating system, as designed by Baker, was a single-pipe circulating system, the water passing from the heater through the pipe coils on one side of the car, then crossing over to the other side and passing through the coils on that side and thence back to the heater. In order to equalize the circulation on both sides of the car, the plan of arranging the cross over at the middle of the car has been frequently adopted when the water is heated by steam. By this arrangement the hot-water circulation is carried, first, to the rear end of the car on the side of the heater, thence back to the centre, whence it crosses over and circulates on the side of the car opposite the heater, thence crossing over near the centre, it circulates on the side of the car at the end nearest the heater. In many cases each side is heated separately, and two independent circulation systems are used, as in Fig. 6.

The location of the steam heater which is to supply steam heat in place of the Baker stove is a matter of some considerable importance, in order that the same system of circulation may apply with either the steam heater or the stove in use. The patents which have been granted show numerous schemes for the location of heaters; they have been successfully used when located above or below the Baker heater and in series or in a multiple circuit with it. Practical as well as theoretical considerations indicated that the best results were obtained when two steam heaters were used, both of which were in series in the same circuit with the Baker heater, one located in the same riser pipe as the Baker heater and the other underneath the floor of the car. With the latter system the upper heater tends to produce a forced circulation by the formation of steam bubbles, whereas the lower heater tends, because of its location, to supplement the circulation produced by the upper heater by gravity

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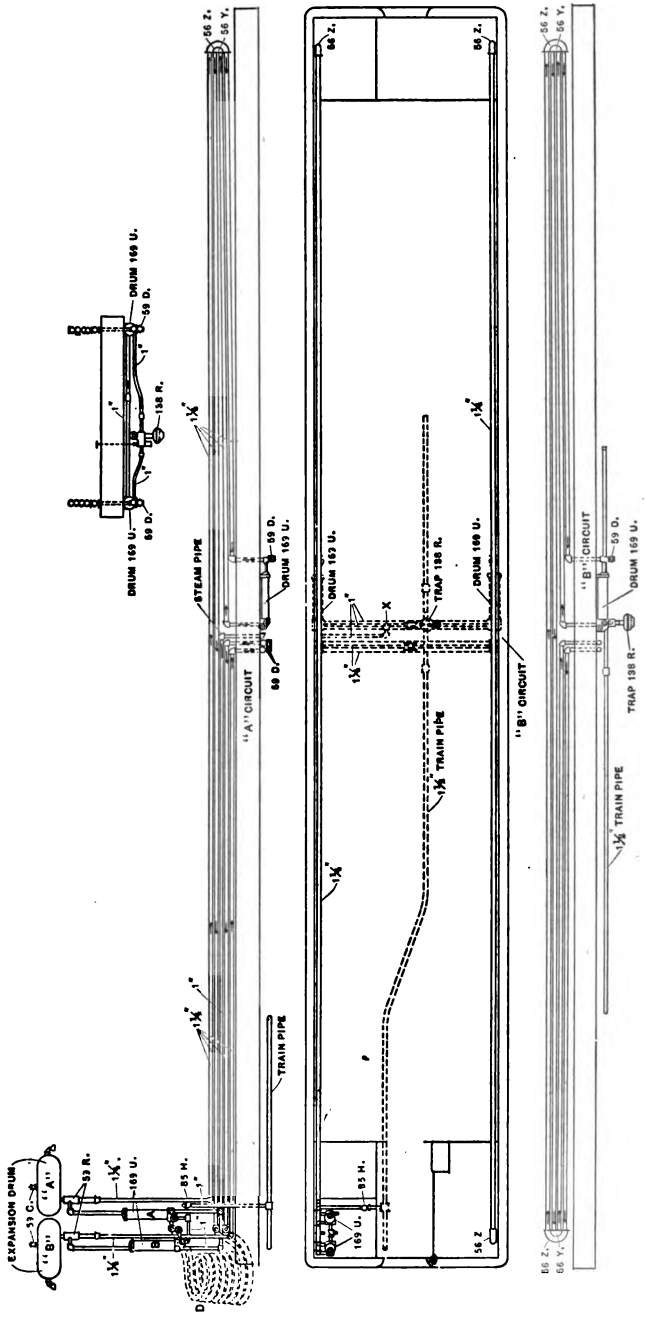


FIG. 6.

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effects; both heaters are useful in warming the circulating hot water. Fig. 6 represents a heating system of this character as applied by the Consolidated Car Heating Company for the heating of the hot-water heating system of a car. In this drawing the coils of the Baker heater are shown as double and by dotted lines at *D;* the pipe supplying steam is marked train pipe. In this system there are two circulating circuits, which are denoted on the drawings as the "A" circuit and the "B" circuit; each circuit has a coil through the stove heater and an upper steam drum denoted for the "A" circuit by *A*, and for the "B" circuit by *B*, and an expansion drum provided with a safety valve and a filling cock; it also has a system of circulating pipes and a steam drum or heater located beneath the car marked 169 *U*. The arrows on the drawings show the direction of circulation. It will be noted that the A circuit is arranged to warm one side of the car and the B circuit the other side, and that the cross-over pipes are located beneath the car. The water of condensation from the entire system of steam heaters is discharged through a single thermostatic trap with a blow-off regulated by a hand valve shown at 138 *R*.

An interesting construction known as the "commingler" system was patented by J. F. McElroy in 1890, and was used in the early nineties quite extensively for warming cars. The general characteristics of this system are shown in Fig. 7. Its princi-

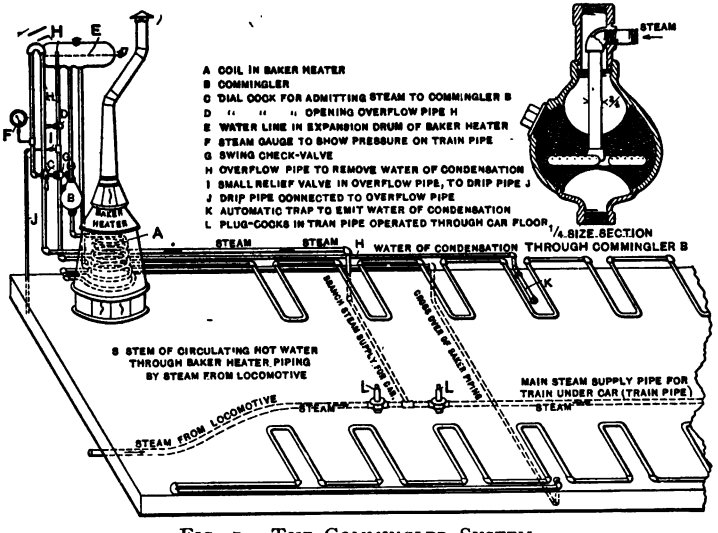
A COIL IN BAKER HEATER
B COMMINGLER
C DIAL COCK FOR ADMITTING STEAM TO COMMINGLER B
D " " " OPENING OVERFLOW PIPE H
E WATER LINE IN EXPANSION DRUM OF BAKER HEATER
F STEAM GAUGE TO SHOW PRESSURE ON TRAIN PIPE
G SWING CHECK-VALVE
H OVERFLOW PIPE TO REMOVE WATER OF CONDENSATION
I SMALL RELIEF VALVE IN OVERFLOW PIPE, TO DRIP PIPE J
J DRIP PIPE CONNECTED TO OVERFLOW PIPE
K AUTOMATIC TRAP TO EMIT WATER OF CONDENSATION
L PLUG-COCKS IN TRAN PIPE OPERATED THROUGH CAR FLOOR
STEAM
WATER OF CONDENSATION
1/4 SIZE SECTION THROUGH COMMINGLER B
BRANCH STEAM SUPPLY FOR B
CROSS OVER OF MAIN PIPING
MAIN STEAM SUPPLY PIPE FOR TRAIN UNDER CAR (TRAIN PIPE)
STEAM FROM LOCOMOTIVE
STEM OF CIRCULATING HOT WATER THROUGH BAKER HEATER PIPING BY STEAM FROM LOCOMOTIVE

FIG. 7.—THE COMMINGLER SYSTEM.

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pal characteristic consists in the use of a "commingler" chamber shown in section at large size at the right. In this commingler chamber the steam enters the water and is condensed therein, both heating the water and forcing a circulation. As shown in the drawing, the commingler is located at *B* in series with the coil through the Baker heater; the steam is taken from the locomotive through a train pipe shown in dotted lines. This method of heating increases the total water in the circulating system by the amount of steam condensed, and for that reason it was provided with an overflow pipe, shown at *H*, to discharge the excess water.

The commingler discharged the steam into the water in numerous small jets through a body of pebbles, and in that manner effected the commingling of the steam and water noiselessly. The temperature of the car could in a large measure be controlled in this system by adjusting the admission valve *C*, since it had the effect of controlling in a large measure the rate of circulation.

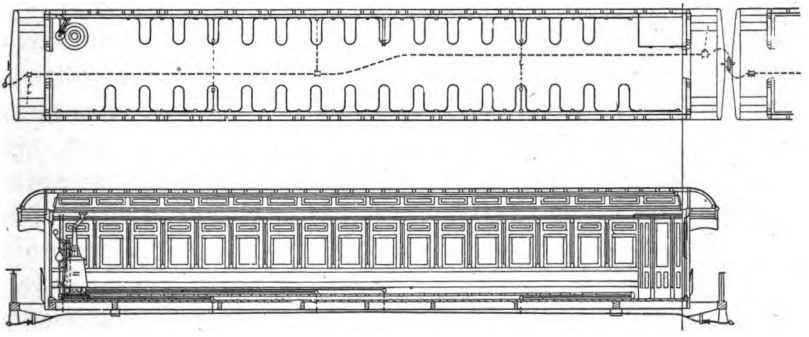

FIG. 8.—SECTION AND PLAN OF CAR WITH HOT WATER SYSTEM HEATED EITHER BY STEAM OR FIRE.

The hot-water heating systems are still used extensively, and present practice does not indicate any material change. Nearly all the Pullman cars are heated with hot water substantially as shown in Figs. 1 and 6.

### *Heating of Railway Cars with Steam.*

At the present time nearly all of the railway day coaches are heated directly with live steam taken from the locomotive, and no provision is made for heating the cars independently with

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stoves or fire. In connection with this system it has generally been found necessary to provide means for supplying cars with steam when they are standing for some time in large yards and are not connected to the locomotive.

The steam-heating systems in use consist of train pipes extending underneath the cars and provided with flexible couplings between the cars which are interchangeable with different cars and which are substantially of the form already described. The steam pipe is connected to the radiating surface in the cars by branch pipes underneath the centre of the car; the radiating surface is drained by an orifice which is jacketed or kept warm by the heat of the steam, which is in a large measure controlled by hand or by a trap; the main train pipe is dripped or drained at the end of the train.

The heating of cars with hot-water circulation by steam is very largely done by special companies, of which the Consolidated Car Heating Company, of Albany, N. Y., and the Safety Car Heating and Lighting Company, of New York, do the greater portion of the business, at least of designing and providing pipe and fittings ready for installation. On the other hand, the installation of steam-heating apparatus is principally done by the car builders as directed by the railroad company concerned.

The heating of railway cars by steam from the locomotive was proposed in the very earliest days of railroading, and is said to have been tried as early as 1851 on the Old Colony Railroad and in Germany as early as 1860. It was put into practical use in Germany as early as 1870, but did not prove successful, and was abandoned.

It was not employed in this country until numerous accidents had aroused the sentiment of the people to such an extent that railroads were forced to take some step looking to the abolishment of stove heaters. In its practical use it has followed in railroad car heating the hot-water heating systems, which have already been described, so although it is the simplest method of car heating, it is also the most recent.

The system of steam heating in use is a pressure system employing live steam. In view of the fact that engines used on locomotives are non-condensing and discharge a great amount of exhaust steam, it would seem, in view of our experience with

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systems of exhaust steam heating for buildings, that the railroad systems presented great opportunities for economizing in this respect. Systems of exhaust steam heating were tried very early for heating railroad cars, but they have never been adopted to any great extent, and can scarcely be said to be recognized or even known in the art.

A suction system employing a vacuum pump on the return pipe was at one time tried on the Central Railroad of Vermont. Other similar systems have been tried, but without practical success.

The various methods of steam heating for railway cars which have been tried cover practically all those known in the art. It is unnecessary to discuss them at length, as the methods involved are not different in general principles of construction from those commonly used in house heating.

*Thermostatic Control.*—The automatic control of the temperature of railway cars has not been generally attempted; it has been employed so far as I can ascertain only in the case of a few special trains. I am not certain whether the attempts at thermostatic control has proved, from the railroad standpoint, a practical success or not, or whether its use is likely to increase or be abandoned. The regulation of the temperature of cars by the attendants is generally erratic, and gives results which are far from satisfactory to the passengers. For this reason the efforts in this direction, if successful, will be highly appreciated by the travelling public. In view of the slow adoption of improvements of this character in the past, it seems probable that very much pressure will have to be applied to railroad companies before such improvements will be generally adopted. The manufacturers must first prove that their devices are practical and operative, and then they must stimulate a demand, otherwise they are quite certain to be neglected.

*Ventilation Systems.*—Our railroad cars are practically without any systems of ventilation. It is true that the cars are built with windows and doors which can be opened or closed, which provide communication with the external air. Any person who has had to spend much time in our railroad cars is painfully aware of the lack of ventilation. In this respect matters are worse than those relating to a thermostatic control because, so far as I have been able to ascertain, no practical system of ven-

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tilation adapted for railway cars has yet been worked out and its efficiency proved by actual successful trial; until this is done, it is useless to urge improvements respecting ventilation upon the railroad companies. I do not see any immediate chance for improvement along the lines of ventilation for this reason, and it seems probable that for years to come such ventilation as is obtained on a railroad car must be had by the opening of windows or doors, and by such service as is given at the present time by the brakeman or other attendant.

### *Radiating Surface Required.*

The average passenger coach, 60 feet long, when heated with hot water is usually provided with 235 feet of 1¼-inch pipe radiation on each side. This is equivalent to 470 feet of 1¼-inch pipe for the entire car, or 205 square feet of radiation. This amount is increased by an exposed steam heater and a little additional surface, probably amounting to 20 additional square feet, making a total for the car of about 225 square feet of radiation.

The temperature of the hot water in the pressure system of circulation employed in car heating can be considered as fully equal to that of steam in a low-pressure heating system.

It is interesting to compare the amount provided in car heating with the amount that would ordinarily be used in a building of the same exposure. For average values of coefficients for heat transmission, and for a temperature outside of zero and inside of 70 degrees F., the following formula for the area of radiation is found satisfactory:

$$R = \tfrac{1}{4}\left(G + G' + \frac{nC}{50}\right) = \tfrac{1}{4}\,(G + G' + G'')$$

in which

$R$ = square feet of radiation;
$G$ = exposed glass surface square feet;
$G'$ = wall surface expressed as equivalent glass square feet surface;
$C$ = cubic contents in cubic feet;
$n$ = number of changes of air per hour;
$G''$ = Glass surface equivalent in heat loss to change of air in the car.

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Under ordinary conditions 4 square feet of exposed wall surface is equivalent to 1 of glass surface, and this relation, I believe, will hold for the sides and roof of the car. The floor of a car is built much warmer than the sides and is less exposed. I consider its value in equivalent glass surface as only one-third of that of the walls which, for the sake of obtaining a basis of computation, I do not believe is greatly in error. The ends of a car are less exposed than the side walls, and I have assumed the value in equivalent glass surface as one-half of that of the side walls. The change of air per hour will depend very much upon conditions, but I have assumed as an average case that it will change twice, or $n = 2$.

Assuming the car as 9 feet wide, 8 feet high at the sides, 9 feet at the centre, and 60 feet long, the following table gives the various elements required for computing the heating surface needed.

The cubic contents will be essentially

$$60 \times 9 \times 8 = 4320 \text{ cubic feet.}$$

TABLE.

| | Dimensions. | Amount Sq. Ft. | Factor. | Equivalent Glass Surface. | Formula Values. |
|---|---|---|---|---|---|
| Side Windows | 120 × 3 | 360 | 1 | 360 | $G$ |
| Top Windows | 120 × .5 | 60 | 1 | 60 | |
| Side Walls | 120 × 3 | 360 | $\frac{1}{4}$ | 90 | $G'$ |
| Roof | 60 × 9 | 540 | $\frac{1}{4}$ | 135 | |
| Floor | 60 × 9 | 540 | $\frac{1}{12}$ | 45 | |
| Ends | 18 × 9 | 162 | $\frac{1}{8}$ | 20 | |
| Cubic Feet Air per Hour | (60 × 9 × 9) 2 | 9,720 | $\frac{1}{50}$ | 194 | $G''$ |
| Total | | | | 894 | |

Substituting the values as above in the formula

$$R = \tfrac{1}{4}\,(894) = 223 \text{ square feet,}$$

from which it would seem that under the ordinary rules for heating a building, a car of the dimensions stated would require 223 square feet of low-pressure steam heating surface.

The above calculation indicates that the practice of supplying radiating surface for heating railroad cars is not essentially different from that used in heating buildings, and the same rules for proportioning surface may be applied.

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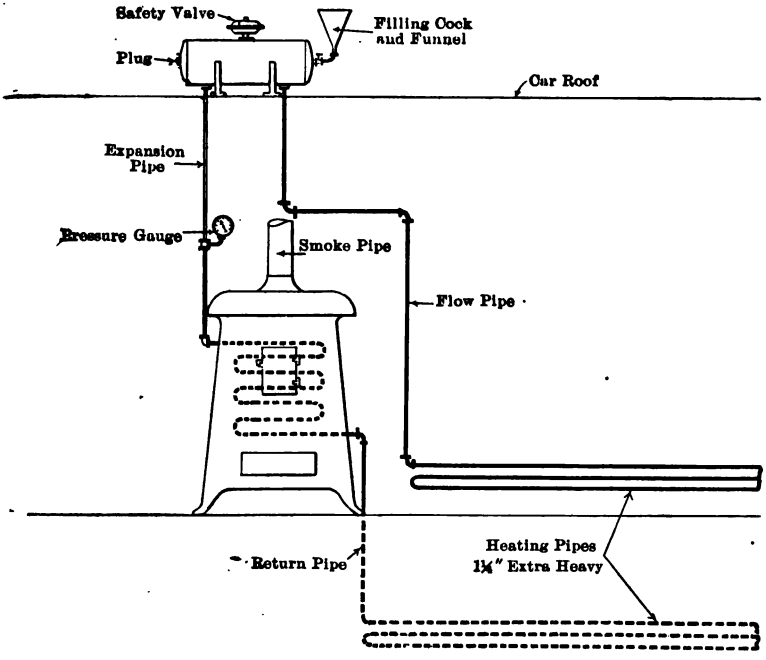
*Conclusion.*—The object of this paper has been to give you a bird's-eye view of the various systems of railroad car heating which have been and are in use, with the hope that it will lead to a discussion which will bring out matters of practical value not only to ourselves but to those interested in railway construction and operation.

The paper has of necessity been rather long and devoted only to general statements and discussions of processes and methods of operation rather than to details of construction.

## DISCUSSION.

Mr. J. S. Davis: The accompanying sketch shows a method of car heating, the safety valve used was nothing more than a




rubber ball held in place by two brass plates, and it was the ordinary practice to run the system at about 25 pounds pressure, and in extremely cold weather the pressure would run up to 60 or 70 pounds. The gauge used indicated mild, moderate, cold, severe. These pressures correspond with a range of about 80

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pounds pressure. At times when the apparatus was not properly looked after, the pressure would run up to 100 pounds or more. Salt water was used to overcome the tendency to freeze, and extra heavy pipe and fittings as well as the circulating coil in the stove were used to provide for the extremely heavy pressures which at times would occur.

Professor Carpenter is right on the question of vacuum systems of heating being used in connection with car heating. Extensive experiments were made in this line on the Pennsylvania Railroad Systems by using a vacuum pump located in the tender of the engine but such systems had to be abandoned where long trains were used owing to the impossibility of circulating steam through the small pipes with a low pressure. If high pressure was used, short circuits would occur which would prevent the circulation from extending to the rear coaches.

Mr. Barron: It strikes me the heating of cars can be done electrically, and ventilation will be done the same way, by small fans to be run by small motors. The railroad companies will soon adopt that solution, or the car manufacturers will. It will be to the interest of car companies to have cars heated with electrical heaters, particularly now when our railroads are rapidly developing into electric roads. I would like to hear Prof. Carpenter's ideas of that feature, because that is a little different, I think, from his line of thought.

Professor Carpenter: This paper has nothing whatever to do with electric car heating or how far it might be carried out in the future. It is very possible and probable that when we get electric locomotives the electric heater will be provided. I do not see how this is going to help us any so far as passengers are concerned and I don't see how the electrical schemes for ventilation are going to come about.

Mr. Baldwin: I would like to give some facts that have come to my knowledge relating to the cost of electric heating as compared with steam heating. I believe it is allowed it costs more to heat a car than it does to haul it. Some years ago I had occasion to determine the values of electric heaters. I remember taking a steam radiator of 28 square feet, to make the comparison, and a summary of the matter is this: The condensation in 28 square feet of steam radiator amounted to about 7 pounds in an hour, or roughly one-quarter of a horse power, while the electric instru-

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ment showed that in the same time, the electric heater doing the same work, used 3 or 4 electric horse power, or about 12 times the fuel value of the steam radiator.

Secretary Mackay: I understand that the Public Service Corporation, of New Jersey, while they did heat their cars with electricity, the same as railway coaches, the seats being heated, they have lately taken out these heaters and placed a small hot water heater, the water being heated by electric heat.

Mr. Brady: The question of heating railroad cars I believe is somewhat solved. We have a negro, who is somewhat of an inventor, in the little town called St. Joseph, Mo. I haven't seen this device but I have run across parties who have seen it, and some of them railroad officials. He has devised a drum and in that drum is water. On the inside of that drum he has an axle made of hickory—just a round axle—and it revolves on that hickory axle, and the friction that is thrown off from that hickory pole or axle heats that water, and, consequently, the car is heated. The power is taken from the axle of the train. They say it is an absolute certainty it does heat the car. Now, I just heard of that several days before I started, and, if I had had time I would have been only too glad to have gone there and seen the experiment. I will say this, that this same darky has this device in his house of eight rooms, and he is heating that house at a cost of twenty-seven cents a day. This is a very interesting subject and I propose, myself, for the benefit of my own research and for the benefit of this Society, to investigate this further. I am satisfied there is something to it. If a man, even if he is a negro, can get up an invention like that, that can heat an eight-room house on twenty-seven cents a day, what will it cost to heat a railroad coach? I thought I would just mention this and set your minds thinking.

It is run by a little gasoline engine—I think he uses that in his house. It is an iron drum, and through the drum runs this hickory axle, and the friction from that axle causes the heat.

Mr. Baldwin: Is that axle in a tube?

Mr. Brady: Yes. I give this to you to set you thinking. The friction is made within the tube. The drum is on the outside of that.

President Gormly: I think if Mr. Jellett would, he could give us some information.

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Mr. Jellett: Reference has been made to heating trolley cars particularly; Prof. Carpenter's paper refers to railway trains. They are different propositions. The trolley cars are opened at every square and constantly chilled by the coming and going of the people—the doors stand open. That is one problem. The other problem is heating railroad trains, the doors of which are only open at railroad stations. The proper heating of railroad trains by electricity is not as difficult as heating trolley cars. That has been demonstrated in a great many ways. There are a number of experiments going on at the present time relative to heating railway trains by electricity, and yet, the men making these experiments are fully aware of the losses incurred in heating trolley cars.

Our own company heated a residence here in New York sometime ago, electrically, and I know what it costs. The owner was in a peculiar situation. He leased the house with the understanding the heating system was satisfactory—and certain other things satisfactory. But when he moved in the heating system was far from satisfactory, the best being 52 to 54 degrees when the weather was cold. He asked for figures for a hot water system and took them to the owner but the owner refused to install the apparatus, saying that it was heated to his satisfaction when he lived in it and it should be to this man's. The gentleman who leased the house found that if he put in a hot water heating system he would have to leave it there when he vacated the house, but if he put in electrical apparatus he would not have to leave it. He asked me to take up the question of heating the house electrically. I raised the point that it would cost as much per annum for current to heat the house by electricity as to put in the hot water system. He didn't care; he didn't propose the owner should get the best of him in that way. He wasn't going to give him a hot water heating system. Electrical radiators are fixtures under the law and not part of the structure. We heated the house, four stories, and his bills for current for the first year were, I believe, about $768. To heat that house, by hot water would have cost about $200 per annum for fuel and the wage cost for the attention of the man. Now, he simply "turns it on."

Our greatest difficulty was keeping finish on the radiators. We had to put shields around the radiators, made out of polished brass and lined with asbestos. We put, first, white enamel on the

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radiators. It peeled off. We tried two or three different finishes. Finally we got a kind of dull black lacquer that seemed to stand very well. The temperature is very high in the radiator itself. We had difficulty to get anything in the way of varnish, or paint or bronze, to retain its color any length of time. This dull, dead black, seems to stand better than anything else.

Taking the question of fuel for warming by water as against the electrical cost of heat, it is about as 1 to 4. The electrical apparatus requires no man to attend to it, whereas I am satisfied this particular house would have required somebody to take care of the heater, or boiler or whatever was put in, which would mean some added expense. But I doubt, counting the labor and fuel, whether the ratio would be more than 2 to 1 against the electric heat.

Using this proportionate cost as the basis of argument, I see no reason whatever why railway trains making long-distance runs, should not be heated in some such way. Although I believe if they put electric energy into some satisfactory method of heating water, they will get the results desired and at less expense.

Mr. Franklin: Please state the approximate cost of electrical installation as compared with hot water installation.

Mr. Jellett: In that particular case the bid for hot water was $1,860. It was heated by electricity for $1,500.

Mr. Harold M. Bush, Columbus, Ohio. (Contributed since the Meeting.) Having followed this particular subject pretty closely (I had charge of the instruction of all trainmen on the South-West System, Penna. Lines West of Pittsburg during the winter of 1903-1904), I venture to give you some of my experiences.

The matter of thermostatic control was tried by the Pan-Handle road as early as 1894 or 1895 and, despite all efforts to make the apparatus then available work under the conditions, was finally abandoned. I had some of the last of these thermostats removed in 1905.

The paper also states that there are no systems of ventilation employed. The Pennsylvania has been using a very efficient and at the same time simple system for a number of years, about ten I believe.

This system when *properly handled* gives the best results. It is equally valuable in winter as well as summer. I am not able to

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let you have any blue prints showing this device as the company does not permit them to go out, but a short description may be of service.

The general arrangement is as follows:

The spaces, on both sides of the car, between the side and first intermediate sills are left clear and free from all braces and filling. This space is connected, at diagonal corners of the car, with a hood, T-shaped, placed on the lower deck. This hood is provided with flap valves which are operated on the inside. These valves are so turned as to present the open side toward the head end of the train. The air thus entrapped passes into the duct and escapes through annular openings in the floor into a closed box. The steam pipes are located in this box and are so arranged as to permit of the air circulating around them. The heated air passes out of the box through tin tubes placed under each seat. The amount of air admitted by the intake is controlled by a butterfly valve located in the down-takes.

The upper part of the car is pierced with six or seven "Globe" ventilators provided with a horizontal disk valve. This valve cannot shut off all the opening as the center or well of the ventilator is not covered by it and is not closeable.

Directions for operating the system are posted in two places in the cars, all trainmen are required to show a reasonable knowledge of it and in addition instructors are constantly on the road, during the heating season.

The worst difficulty experienced with this system comes from the accumulations of cinders that lodge in the horizontal duct, and in the older cars they even fill the steam box. Traps are therefore provided in the bottom of the duct and the car inspectors are required to open them at the terminals. I have removed as high as five barrels of cinders from one car that had been neglected.

In the coach yard at one of the Pennsylvania terminals this equipment will be found on all the electric lighted cars lettered "Pennsylvania Lines" and numbered in 7,000 and 8,000 series. The latter series belongs to the southwestern system where a great deal of attention is paid to the proper working of this device.

We figure that a steam pressure of five pounds per car in the train is necessary to get results when the thermometer is above

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zero. I have used as high as 10 pounds per car in extreme weather and have had reports of even greater pressures being necessary.

In regard to a vacuum system: This was the first system used by the Pennsylvania and was a dismal failure. The inability to maintain any vacuum whatsoever on account of the impossibility of making joints between the cars that would not leak air seemed to be insuperable.

The paper makes no reference to the "Two Pipe" or Return System in use on the Pennsylvania up to within the past three years. This system was most complicated but gave satisfactory results on short trains.

The sketch of the C., M. St. P. & M. connection should show the connection at the line of the lower deck instead of slightly above the platform end rail.

I should add to the description of the Pennsylvania ventilating system that the deck sash are sealed in place and have no part in the scheme. The windows are made as tight as possible; double sash being advocated and used in special cars.

The standard train line is 2-inch, covered with magnesia. In this connection I recall a car that got out of the shop without the piping being covered and it ran a whole year without the covering being applied. I had a special investigation made of the record of this car in that time and found not a single complaint regarding its heating or even any report from the trains it ran in. This incident is a curiosity and no criterion. What the complaints would have been if the condition had been discovered by some captious trainman only experience with them would indicate.

Your estimate of the heating surface is correct but as we suffer more from cold cars, with the ventilation system, I feel that it should be increased.

Steam jacketed traps are not a success, as they freeze up soon after the locomotive is taken off.

Thermostatic traps of the Gold type give the best results. Two of these are used on each car, one on each side. We frequently run a car using only one side.

The author is to be thanked for the article which condenses into a small space much that has never been published.

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## AUTHOR'S CLOSURE.

The foregoing paper by Mr. Harold M. Bush was received in the form of a letter. It contains, however, so much general information that I submit it for publication in our Proceedings as a part of the discussion of my paper on Railroad Car Heating. The letter from Mr. Bush points out the fact that something is being done in the way of ventilating cars by the Pennsylvania Railroad.

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# CLXXVI.

# TOPICAL DISCUSSIONS.

## TOPICS FOR DISCUSSION.

No. 1. "Relation of steam and return connections to horse-power in heating boilers."

No. 2. "Size of safety valve for heating boilers, under varying pressures up to ten pounds."

No. 3. "In the so-called fan or forced blast system of heating, how should the amount of heating surface in the tempering and heating coils be determined in view of the variation in practice?"

No. 4. "Fuel required to operate a district heating plant and electric plant combined using exhaust steam for heating, as compared with a heating plant alone using direct steam."

No. 5. "The air space required through hot blast heaters."

No. 6. "The relative healthfulness of direct and indirect heating systems."

No. 7. "The variation of the boiling point under the same degree of vacuum at different altitudes."

No. 8. "Rated surface of radiators versus actual surface."

No. 9. "Durability of steel and wrought iron pipes used as returns for exhaust steam heating, also when high pressure steam free from oil is used."

No. 10. "Expansion of pipes due to heat from steam, high pressure 100 pounds and upward, and 10 pounds and under."

No. 11. "Advantages of standard dimensions of radiator valves and connections."

No. 12. "Should the guarantee of efficiency be assumed by the heating engineer who designs the apparatus, or the heating contractor who installs it?"

Of the above topics only Nos. 6, 8, 11 and 12 were discussed, as below:

## TOPIC NO. 6.

"The relative healthfulness of direct and indirect heating systems."

## DISCUSSION.

Mr. Franklin: A couple of years ago, in a house heated with hot air, a lady was troubled with asthma. It was impossible for her to have any comfort. After the indirect heating system was installed her health was very materially benefited.

Another customer, who had a hot water apparatus installed

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in his house instead of a hot air furnace, found the health of his children, who were always complaining of colds, sore throat, etc., much improved. On the installation of the indirect hot water system, colds and sore throats disappeared.

These are facts which have occurred to me since this question has been read.

Mr. Baldwin: Twenty or more years ago Congress appointed a committee to investigate systems of heating and ventilation, and on that committee there was a Dr. Burns, of Honesdale, and a Mr. Jadwin, a Member of Congress from Pennsylvania. Furnaces came into the investigation and the committee came to the conclusion that tonsilitis and diseases of the throat were caused by furnaces, or by leakages from furnaces.

At that time Honesdale adopted its first system of steam heating. Messrs. Jadwin and Burns were both members of the School Committee of Honesdale, and they had a lot of statistics as to sore throats in the Honesdale schools. Information collected showed that something like 80% of all the scholars, in an ordinary winter, had tonsilitis. But after the installation of proper steam-heating apparatus, in the same school they got a percentage of only 11. The Congressional report is, of course, a matter of record. But Dr. Burns, of Honesdale, and Mr. Jadwin and the directors there, I think, will confirm these figures. They are approximately correct and seem to confirm the suspicion of the Congressional Committee.

This was due presumably to the impurities that came up with the air. When we burn coal and there is complete combustion, we have carbonic acid, which is not a good thing to breathe. When we burn coal with incomplete combustion and it gets into the air flues we breathe carbonic oxide and are breathing poison, and one-half of one per cent. in the air will kill a man. One per cent. of illuminating gas in a manhole in the streets of New York will kill a workman. The proportion of carbonic oxide (CO) in illuminating gas being about one-third, therefore, one-third of one per cent. of carbonic oxide kills. Every man who runs a hot-air furnace and is endeavoring to save coal by partially closing the damper makes a gas retort. It is done so that some fire will be there when he gets back many hours later. It is the custom and adds to the danger from a furnace. A furnace that will not leak, is probably no menace.

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Secretary Mackay: I want to ask Mr. Baldwin if he knows whether the apparatus taken from these school buildings was replaced with steam-heating apparatus—a modern installation such as is placed in the school buildings of to-day?

Mr. Baldwin: The furnaces were the ordinary hot air furnaces of twenty-five years ago and indirect steam radiation was substituted.

Secretary Mackay: I want to know if it was modern hot air installation, or if it was the old style of hot air put in, with small pipes and high temperature.

Mr. Baldwin: I think it was the old style, small pipe hot air furnace. Let any man who has a furnace in his house hang his silver watch on the face of the register and see how quickly it will turn black. That is an indication of sulphur. Put a piece of silver on the register and another on the bureau and see how quickly the one on the register becomes black. The presumption is it is caused by sulphur. That shows that one element of combustion is coming into the room, and why may not all be present. I am not prepared to say the modern hot air furnace is not open to these objections.

Mr. Chew: What Mr. Baldwin has said is only true where he has overrated the dangers. I have been connected with the furnace heating business since 1875, and to the best of my knowledge there are infinitely more houses heated with hot air than with any other kind of system. Even the hot air furnace has been accepted by the people on the farms as a pretty good institution, instead of the stove.

When a man puts a small flue in a partition, I think he has provided the cause of a great deal of the trouble with furnaces. If you will follow in detail, any man who speaks against furnace heating, as Mr. Baldwin has, you will find he speaks of a system where there are high temperatures. I have had some men think I was speaking an untruth when I said I have seen water boiling in a brand new tin cup fifteen feet away from a hot air furnace. You could not do that with either a steam or hot water radiator under ordinary conditions. That is not the type of furnace system a member of this Society would recommend.

And this brings in Mr. Franklin's point—asthma. Next door to me is a man whose wife is suffering severely—about six months laid up with asthma. I have told him he ought to enlarge

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his air supply and piping so as to have a warm air system and also that he should provide means for adding artificial moisture. The air going from the register in one room will take one quart or more of water a day, I know from experience. Sometimes three pints or more. I have used a pan of water placed near the register and a towel, with the end in the water, hung over a wire frame so that the warm air would strike against it as it flowed from the register. My experience shows to my mind the need of artificial moisture in the heated air. The custom now is to leave the water pan out of the furnace, as shipped from the founders. This I believe to be a step in the wrong direction. In my own house I have found the thermometer 77 or 78, with the humidity below 30. I filled the water pan in the furnace and started the evaporation going and was more comfortable as the temperature fell and the humidity rose.

I think Mr. Schaffer will support me in pretty much everything I have said.

Mr. Schaffer: The trouble in furnace heating is due to poor work. Especially do we find the overheated furnace in sections where they use natural gas—they call it a furnace, but it is nothing more than a galvanized funnel with a register on top, and the gas flame, going up through the center, draws the air from the cellar, or wherever it can get it, and up through the floor into the house, allowing foul air, dirt and dust to enter the house with this hot air or natural gas. That is certainly, in my opinion, rank poison. And yet they call these furnaces. A man sitting in the house and smelling these fumes thinks there is something the matter with the furnace. But, I do say, furnace heating can be done right.

Mr. Baldwin: The question of moisture is entirely overrated. I do not want to hold it is not necessary to have a certain amount of moisture, but moisture in the air will never counteract poisonous gases. It is true that the temperature in small pipes is high, but we do not breathe it at that high temperature. It diffuses in the room and then we breathe it at the temperature of the room. So I don't know that that can be argued.

There is a man present—to go back to the question of tonsilitis—whose house was warmed by a furnace. I said to him: "I will not visit you in winter while the hot air furnace is in your house. I smell it the moment I enter your door. You are

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sick all the time in winter and your family is sick." The doctor cut his tonsils off but he didn't get well. He changed his furnace for a hot water apparatus and has never had an attack of tonsilitis since.

Mr. Brady: The question of heating by hot air furnaces I know very little about when it comes to house heating, but when it comes to the question of schoolhouse heating by furnaces I know something about that. I have had in the neighborhood of twenty-two years' experience with reference to the heating of school buildings. We have to-day a few furnaces in some of our school buildings, without fans and with fans. I find that without the fan we have a great deal of trouble with escaping gases and bad odors coming from the furnaces. With a fan behind the furnace we find we have very little trouble. It has given better satisfaction than the furnaces without the fans. The janitors, of course, are a very energetic lot of men and believe in taking advantage of their work by piling the furnace fire box full of coal and then going around and hunting work to do. In cases like that, on a cold day, I have gone in and found that the furnace box or fire box was red hot and the inflow of air seemed choked off. Going into a room you would pretty nearly stifle. With a fan behind it, it cannot happen that way. I don't want to condemn the furnace system, while I have always been a strong advocate of steam and hot water, but steam is preferable for school buildings, either the direct or indirect low pressure system. The furnace heating of a school building is quite a problem. If you leave it to the furnace manufacturer to design the size of the flues and the size of the furnaces, you will find that you will come out very short of heating your building. But with a competent engineer who can lay out the fan and proper areas you won't have so very much trouble. By giving a good sized fresh air inlet and having a good, careful man to take care of the furnace, I believe that for the ordinary country school districts or suburban districts the furnace is all right. But when it comes to a metropolitan city, where the city is crowded for room and land is expensive, why, of course, I then prefer the hot blast and fan system. I know with the furnace system you would have to watch and see that all joints are kept tight. Whether it be a cast-iron furnace or steel furnace, it is bound to open up the joints by contraction and expansion. So I don't want to con-

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demn the furnace system, while I am a strong advocate, and always have been, of steam heat and hot water.

Mr. Baldwin: Reference has been made to air entering a room at 110. I will say it is proof positive that you are not getting sufficient air, not getting ventilation enough in a schoolroom when you find air entering at 110 degrees. The quantity of air necessary for proper ventilation to enter a schoolroom at 110 will carry more heat than the windows and walls can cool under the most extreme conditions which can exist in North America. So when one enters a schoolroom and finds the air is coming in at such a high temperature, or even much above 80 degrees Fahr., he can make up his mind there is some doubt about the ventilation. If he finds the air coming in at only 80 degrees Fahr., or lower, on a pretty cold day he can also make up his mind that the schoolroom is getting pretty nearly 1,800 cubic feet per capita per hour and that the ventilation is good. If the air feels hot to his hand he should be suspicious of the quantity. It is one of the rough methods of judging by the temperature. It is a simple one and approximately correct. Judgment can be made by it. The engineer can readily make up his mind as to the amount of air coming in by the temperature at the register and the temperature outside. Probably 85 or 90 is as hot as 100,000 cubic feet of air can enter a schoolroom in an hour without overheating it. The doors and windows of an ordinary schoolroom under ordinary winter conditions will not transmit much more than 40,000 B. T. U. in an hour. The average is not equal to this.

Mr. Chew: By putting in round risers you get a good flow or volume of air at a low temperature—instead of air at a flame temperature. I think it will be of benefit to the furnace trade if in some way we can induce the architects, carpenters, builders and furnace men, who are as bad as anybody else, to stop putting these little flues in partitions and induce them to put in something that will allow for the passage of a volume of air.

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## TOPIC NO. 8.

"Rated Surface of Radiators versus Actual Surface."

### DISCUSSION.

Mr. Wolfe: I am interested in that. I don't say the manufacturers are at fault intentionally, for I believe they are honest. I believe if the radiation was guaranteed the engineer would have a lot of trouble saved, because he could say there are so many feet of radiation guaranteed. I would make the suggestion that the Committee on Standards select some thoroughly competent man who knows how to measure radiating surface; the radiator manufacturers submit to the Board of Governors samples of their radiators of various sizes and that the manufacturers pay the expense of the test, the test to be made absolutely, or nearly absolutely, under the same conditions—all alike. I make this as a suggestion that the Committee on Standards appoint a man, the manufacturers to pay the expenses of the whole job.

Secretary Mackay: I don't want to go on record as recommending the manufacturers to give 10 per cent. less than the goods paid for, but my trouble has been not so much a lack of surface or shortening of surface as it has been a lack of air space in the ordinary type of two, three and four-column radiators. I believe that is of as much importance as the giving of the whole amount of surface the manufacturers claim to give.

Mr. Brady: Some years ago I was called upon to pass upon a certain installation in which the owner, the architect and heating contractor got into a squabble. The heating contractor claimed he fulfilled the specifications to the letter. The architect specified the style of radiation to go in, the number of loops and number of square feet of radiation. This particular contractor furnished the radiation and they were at a loss to know why the building would not heat up to 70 degrees in zero weather. After calling in several disinterested parties, each one of them had a different idea, one claiming that the boiler was too small, another claiming the mains were too small, and another claiming the radiation was lacking. They called me in, and I think it lacked about 2 degrees of being zero. I found that the whole trouble lay with the radiation, not that there was not enough

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radiation in the room, but the way the radiators had been finished. The architect's specifications called for three coats of white enamel, which is about the same as asbestos. So to settle the question I decided in certain rooms that they would get four radiators, I think it was, the same size as the ones then in place, and turn on the same amount of steam, under the same conditions, and they would see that the mains worked all right, that the radiation worked all right and the boiler worked all right. I told them to go ahead and make that change and if it did not give satisfaction I would pay the expense. They had no further trouble at all, and yet the radiation was condemned, the boiler was condemned and the piping system was condemned. So you can plainly see the whole fault lay with the architect. Of course, he wanted the radiators decorated nicely, which they were and looked very pretty.

Mr. Baldwin: Mr. Brady has conveyed the idea that paint interferes with radiation and he has likened paint to asbestos. Asbestos itself is a pretty good conductor. The transmission of heat through the iron or through the paint is dependent more on the vehicle taking the heat away than on the nature of the surface. Really the thickness of the metal and thickness of the paint has some slight effect on transmission, but efficiency depends on the movement of the air outside and in contact with the pipes. The value of paint as a preventive of the transmission of heat is very small. I do not say it has not some value, but we must not overestimate that value. We must paint our radiators very frequently and must not be afraid to do so when they need it. The paint is a negligible quantity, the transmission depending on the movement of the air. Set a radiator up perpendicularly and one result is obtained. Put it at an angle of 90 degrees or 45 degrees and the room warms in very much less time. This is actually the case. Turn it over and the air will pass it in a different way altogether. The thing to bear in mind in selecting radiators and considering efficiency is the way the air comes in contact with the surfaces and passes over them.

Mr. Schaffer (Addressing Mr. Brady): Was the job satisfactory after the change was made, and was the whole building changed?

Mr. Brady: That was all the change made. But the radiators were taken out and the same number of radiators put in their

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place with one coat. The heating contractor got his money. The architect was satisfied.

Mr. Thomson: About a year and a half ago I had a disagreeable experience. I prepared plans and specifications for a heating system, the contract for which was awarded to a local contractor. The style of radiators was specified, but the number of sections in each radiator was not mentioned in the specifications. When the radiators came on the job they appeared quite small, therefore I measured them. I found that the indirect radiators were about 18 per cent. short. The standard height radiators were nearly the same as rated. The other sizes, not standard height, were a little short, some 8 or 10 per cent. To verify my measurements I called in a mechanical engineer, who, being at one time a skilled toolmaker and accustomed to micrometer measurements, I considered to be an expert on this rather exacting class of measurements. He measured the radiators very carefully and his measurements were all practically the same as my own. I notified the contractors, calling their attention to the shortage of radiation and they, realizing the justice of the case, immediately furnished sufficient extra radiation to compensate for the manufacturer's shortage.

It seems a hard thing on the contractor, it is a hard thing on the engineer, and a hard thing on the owner to have to bother with radiation not correctly rated. The owners suffer because the buildings are not properly warmed during cold weather, as they would be if the radiators were full measurement. It is disagreeable for the engineer, because to keep tab of radiator shortage he has to measure radiators for himself so that he may know what excess to allow for shortage. And it is rather demoralizing to the contractor to pay for something he does not get.

Mr. Barron: I want to ask Mr. Wolfe a question. Doesn't he feel, comparing the actual surface with the rated surface, that there is a difference, on an average, of about 20 per cent.? In other words, radiators on an average are rated about 20 per cent. above their actual radiating surface.

Mr. Wolfe: Yes; I think so. (Laughter.) I think they are made according to certain diameters.

Secretary Mackay: My experience is that some radiators are anywhere from 5 per cent. to 10 per cent. short of surface, and that some four-column radiators would show 20 per cent. less

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efficiency than the two-column or three-column, due to construction or type of radiator and lack of sufficient air, from the fact the inner tubes radiate against the outer ones. There is not always that difference, for some of them measure up full, some measure 5 and some 9 per cent. short. I don't believe I ever found a radiator more than 10 per cent. short.

I had a case in a large building where I had specified a certain make of radiator, and the manufacturer "got wise" and raised the price on the contractor two cents a foot. The contractor came to me and wanted to put in another make of radiator. I at first objected but finally consented, because I thought it was an imposition on the party who got the contract. I wrote him to change the radiator on condition the manufacturer would furnish 5 per cent. more radiation of the kind that he wished to place there in place of the kind I had specified. I believe the radiation placed had as much surface as the radiation specified.

I think the engineer and contractor should place this factor of safety in his apparatus that is eaten up by shortness of radiation or poor construction, and you will give satisfaction, not because 100 feet of radiation has got 100 feet in it but because the engineer or contractor has figured a factor of safety of 10 per cent.

## TOPIC NO. 11.

"Advantages of standard dimensions of radiator valves and connections."

### DISCUSSION.

Mr. Donnelly: If we had standard dimensions for radiator valves, the valves would be interchangeable, and a man buying a stock of one style of valves, wishing to shift to another, would not have to educate the steam fitters to the new set of dimensions. Valve manufacturers would not be troubled with putting out so many small sheets of dimensions, which it is necessary for the steam fitters to carry in making proper allowances when installing radiator connections. With standard dimensions, when there is trouble with worn out or defective valves, it would be of great advantage to be able to substitute any valve without going to the trouble of finding out who made the valve or what the dimensions were, as it is sometimes almost an impossibility to secure another of the same dimensions. Standard dimensions

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of radiators have come about as a natural demand, and almost all sections are on 2½-inch centers. I know of a case where a certain valve was specified, and afterwards it was changed to one so radically different that special valves had to be made. There is a great variety of dimensions in the special styles of automatic return valves. Some of them are of great length, longer than the ordinary radiator valves, and some are longer from the center to the bottom. Again, some are made ½ inch and some ⅜ inch. In Europe a great many return valves are made ¼ and ⅜ inch. We have not got down to quite as small as that. An engineer specifying a special system, in the way of appliances for radiators, might do well to call for certain standard dimensions of valves and connections. If it proves satisfactory, well and good; if not, it is less labor to change it to something else.

Mr. Jellett: This is purely a commercial question and is of slight interest to this society. There is only one way to establish uniformity in the matter of appliances used in steam and hot water heating, and that is through people who buy these appliances. The National Association of Master Steam Fitters has had a committee of that kind for some time. Some years ago this association, together with the manufacturers, established standards on flanges, and they are now hard at work on standardizing fittings and other materials. Charts presented at the last annual meeting showed a great divergence of weights and dimensions of cast iron fittings, and the Committee of the Master Steam Fitters has under discussion at the present time how to handle this with least loss to the manufacturers. They are all working to standardize all classes of materials used for steam fitting, and it is a matter that will take considerable time. That committee will make greater progress than a committee from this society can, because that association buys material. I don't believe in making specifications that a valve shall be of certain length over coupling, certain thickness or diameter, or anything of that kind. If the Association of Steam and Hot Water Fitters will say to the manufacturers, "We will buy our valves from you if you make them to a standard," they will be more likely to take notice. This society should devote its time to standards of engineering methods and not to the way manufactured articles should be made.

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Mr. Brady: I agree that this is a commercial question as to the size of valves, and Mr. Jellett is right when he says the Master Steam Fitters have taken this matter in hand.

In answer to my friend, Mr. Donnelly, as an engineer I will say this: I arrange my specifications in such a way that I select from four to a dozen different valves which I deem advisable, which I consider good valves, and I allow the contractor to take up any one of these valves—but they must be all alike. In my work as a schoolhouse engineer I use very few valves above the basement. As stated here this morning, I am an advocate of the fan system. So much so that years ago I invented a heating and ventilating system, and I thought at that time it was the best I had ever seen. After I investigated the fan system I came to the conclusion that the best thing for me to do was to abandon my system, which I did, after installing it in quite a number of our school buildings, but which to-day are giving satisfaction. At that time it required quite a number of valves, and I found, as Mr. Donnelly says, to make repairs I had a good deal of trouble. So I abandoned that kind and took up the fan system, and by improvements to-day I find that all the valves I need are in the basement. I have very few radiators in the buildings—possibly a few in the halls.

Now all risers I run to the radiators are 2-inch, first floor, second floor and third floor, and I use standard size valves, 2-inch, and nothing else. In addition, I will say that any of you who visit Washington to-day will find they are still using ¾-inch and ½-inch valves and the two-pipe system. But to get information concerning the heating and ventilating system you don't have to go to Washington. The weights of valves, I do not think, should be entered into by this Society.

Mr. Donnelly: A committee from the American Society of Mechanical Engineers and the Master Steam Fitters considered it a proper engineering question to establish dimensions of flanges. If that is a proper engineering question, and I think it was for the American Society of Mechanical Engineers, I think this is a proper question to be discussed by the heating and ventilating engineers.

Mr. Schaffer: Some time ago I ordered some valves taken off an old heating system used for a great many years, and I wanted to specify standard valves that could be put on that system. The

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contractors told me it would involve a great deal of trouble and they didn't think they could put them on. I sent out a list to get sizes of valves, and I found, after tabulating all my data, they ranged from 1/4 inch on 3/4-inch pipe to 5/8 inch on 1 1/2-inch pipe, and the thread dimensions varied from 11-16 inch on 3/4-inch pipe to 3/4 inch on 1 1/2-inch pipe. That shows about the rate of variation in the sizes of valves.

Mr. Barron: It wouldn't be a bad plan for us to work with the Master Steam Fitters or with a committee of the Mechanical Engineers if they have any such thing under way. If the engineer could by specifications specify a certain 1 1/4-inch valve, standard valve, of such and such a make, it simplifies the work and it is in the direction of progress.

## TOPIC NO. 12.

"Should the guarantee of efficiency be assumed by the heating engineer who designs the apparatus, or by the heating contractor who installs it?"

### DISCUSSION.

Mr. Brady: I believe that is a very good topic. I believe wherever there is a consulting engineer or heating engineer, and he is conversant enough with modern practice to prepare a set of plans and specifications, he should be held responsible. I believe if this is carried out that there will be better work done and better satisfaction given.

My work may vary from others, but as the work progresses I issue estimates from time to time and, when I get the final estimate, it doesn't make any difference to the contractor whether the job works nicely or not. I am responsible. I have to make that good at my own expense. I do not think a man should put himself up as an expert and prepare plans and specifications unless he is qualified. I think it is an imposition on the owner to get the confidence of a man who is incompetent to prepare plans and specifications for a satisfactory heating plant. Therefore, I think that the heating engineer who prepares plans and specifications should be held responsible for the working of those plans.

Mr. Franklin: The contractors are to carry out the engineer's specifications and plans, then somewhere in the specifications is a certain clause, a certain amount of radiation specified to be the

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minimum quantity to be accepted. The contractor must furnish that amount of radiation. It seems to me that Mr. Brady has the right idea in reference to preparing plans and specifications. We find in Boston that some of our engineers entirely refuse to guarantee anything in connection with their heating plans, and are ever ready to throw the responsibility on the contractor.

I have a case in mind where a certain engineer called for certain work and his superintendent directed exactly how that work should be performed. Then, because of failure of the work to produce results after it had been constructed under the direction of the superintendent, the engineer demanded of the contractor that he go to the expense of some $600 or $800 to make good the deficiency at his own expense. The contractor refused and the matter was referred to the commission that had charge of the building. A clear statement was made of the facts and proof was given to the commission as to the directions given, and the commission, while they took the ground that the contractor was at fault and must make good, they were obliged to allow the contractor the cost of performing that work.

If the engineer is not capable of laying out work to produce results he should not throw the responsibility of his failure on the contractor. I believe there should be a sentiment—not only a sentiment, but it should go forth that it is the sense of this Society—that every heating and ventilating engineer should be responsible for results. In connection with this room, if there is a lack, as there appears to be, why should the contractor be called upon to make good that deficiency? Here is a plant laid out by a competent engineer. This plant is doing all that it can do, and why shouldn't the engineer be responsible and make good the deficiency and pay for it? I believe we would have more careful work at the hands of the engineer. I believe if the responsibility were put upon him and it were understood that he was responsible and would be obliged to make good in case of deficiency there would be less criticism. He should be careful what he specifies and how he makes his calculations. When the contractor has carried out the specifications called for and fulfilled the requirements according to the specifications and plans his part of it should cease. Such an expression by this Society would lend an influence that would be felt throughout the country. Every engineer would feel that he had lowered himself in

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the sight of all other engineers, the community and the public at large if he failed to make good. I believe that this Society would perform a great benefit to the public at large and to the heating trade generally.

Mr. Munroe: This is a subject on which those of us here will be divided, some of us on the side of the contractor and others on the side of the engineer. I am on the side of the contractor. It has been said that the minimum amount of radiation should be noted on the plans. I don't agree with this at all. If a minimum amount is named by a designing engineer, he puts it up to the contractor or estimator, who, within a period of one-half day, more or less, has to take off or estimate on a set of plans and specifications, sometimes quite voluminous, which took from a week to three months or six months to develop and lay down if the job is a large one. It is simply a matter of impossibility for the contractor, or, say, twenty contractors who may be bidding on the job, to spare the time of their estimator to check up the quantities of radiation shown on the drawings. It puts him in the position of consulting engineer. He is not getting a commission for checking up the designing engineer's work. He is thrown in a position of having to make good, if he is fortunate enough to get a contract at a small margin of profit, when he gets the contract, designed with radiation of a minimum amount, assuming the responsibility of results, he has to assume the responsibility of results due to the construction of buildings prevalent to-day, with metal sash and concrete walls, etc., which requires, as we all probably have learned by this time, anywhere from 10 per cent. to 50 per cent. additional radiation by our standard rules for warming buildings. A man as a contractor cannot afford to protect himself to the extent of bidding on that much additional, so far as his judgment goes, and adding surface in his estimate, which don't only mean radiation and pipe but labor. He has to, as I say, cover himself by an amount of radiation, etc., which, at the high costs to-day, will invariably run his estimate up to a figure which puts him entirely out of the running. He would hardly be able to go ahead with the quantities given and land one job out of ten. I dare say there is not a contractor in the room that will disagree with me on that point, because there will be "others" who will be willing to guarantee anything, at any time and under any consideration.

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The consulting engineer has every right to assume the responsibility for anything he puts on the public, and, if he hasn't that right, I say he should go out of business. He should not throw on the contractor the responsibility that he is not willing to assume himself. On the other hand, if he names a quantity of radiation for each room that he believes is sufficient, he has a right to make that radiation sufficient to be absolutely sure that he is right. Let the constructing engineer bid on such plans as will absolutely give results. It is an imposition on the contracting engineer to have to put up with the conditions that exist to-day. I realize the fact that there are plans gotten out and cooked for certain contractors. Those of us who are wise enough can conceive this scheme and get in the running. To my mind I do not think the first cost of ample radiation is sufficient to justify the designing engineer to put a minimum amount in a building. He has a right to put a maximum amount in a building, for that is what he is employed for, to get an apparatus that will do the work in the most severe weather and under the most severe conditions.

The constructing engineer, assuming a contract on a set of plans designed by a competent designing engineer, should be held responsible entirely for the circulation in every part of the system that is put up by him on these plans. If for any reason whatsoever these plans are not designed in a way that circulation will occur he has a right to discover that, because a competent constructing engineer can discover these conditions, as it is practically impossible to design a plant on paper which will not have to be modified; therefore, the constructing engineer is responsible for the circulation and filling of every part of that system with steam and in that way get results from the system designed.

I hope the Society will take the stand now, or at least shortly, exonerating the constructing engineer from this responsibility, which is, indeed, a serious one.

Mr. Barron: There is a commercial side and I want to request the Chair to ask Mr. Rutzler, who is here, to give us his views on this question.

Mr. Rutzler: I agree with all that has been said except one portion of the remarks of the last speaker. He seemed to think the responsibility for circulation should rest with the contracting engineer. But, if the pipes are not large enough, I don't see why

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the contracting engineer should be compelled to guarantee that. The designing engineer should have a little more to do with it than laying out surface in rooms, and laying out pipes, valves, etc., of sufficient capacity. Otherwise, I think everything has been said I would say on the subject and I approve of all that has been said.

Mr. Hopkins: I think the average contractor would be more interested to have the business of making plans and specifications taken out of his hands and the consulting engineer paid for making these plans and specifications, because the contractor don't get anything for them. He seldom, if ever, figures the cost of making plans in estimating the cost of doing the work. When he gets through he has done an engineering service without compensation. I have been associated for a number of years with a concern that did business both in contracting and consulting and they pursued this plan: They made plans and specifications that were approximately correct as to details and bills for lumber and they guaranteed the price. If the owner was unable to get a price as low as the one they made, they, themselves, would work at that price. If the contract was given to another party they would pass upon the work from time to time, and when finally certified to the responsibility of the contractor ceased entirely and that of the owner commenced. If the radiators were small, or the pipes, or boilers, or engines, or anything else, the consulting engineers made good at their own expense and never asked the contractor to repair a leak after they passed upon the work.

I think that the contracting engineer has no objection whatever to turning over to the consulting engineer the preparation of all plans and specifications for heating and ventilating work. But the contracting engineer, when he does that, wants to turn over at the same time all responsibility for the success of the plans, the consulting engineer to be responsible for the mechanical construction of the plans according to the plans and specifications. And if the consulting engineer is not willing to assume the responsibility of the plans and specifications he puts out, the man is not worthy of being an engineer, and is paid for something which he has not delivered.

Mr. Jellett: You say the consulting engineer should guarantee results. Not always. Yesterday I issued a certificate, and I

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knew at the time I issued it that part of the building was not heating satisfactorily; not the fault of the contractor at all, neither the fault of the plans and specifications. The architectural plans were for a building 280 by 85 or 90 feet, with double sash. After that, the construction had been changed to put in swinging windows, swinging out, and they worked those windows with a series of chains. I went there on Tuesday of this week to make an examination—it was very cold, temperature outside 10 degrees—and I found 80 per cent. of the windows were open three-quarters of an inch to an inch and they could not close them.

One gentleman has said the consulting engineer ought to put in the maximum. That is not good engineering. You are employed to spend the owner's money and spend it to the best possible advantage. You are supposed to design an intelligent plan to give only the results desired. The owner invests so much money and expects so much in the way of results for that money.

The heating contractor is an engineer. He has to be to get results from a great many of the plans and specifications from which he works. The concern of which I am an officer started out with a determination they would make a charge for plans and specifications. If we are to do the work we will charge for the plans and specifications to carry out the work, as part of the expense of carrying out that work. We have always taken this position. The result is, without being egotistical, our engineering business in Philadelphia is double that of any other engineer in the City of Philadelphia—and we are also the largest contractors in our line of business. It is not merely that we have acquired a certain amount of technical information, but we have paid what it cost to get experience and learned how to do business.

In this discussion you leave the owner out entirely, and it is a mistake, because he is frequently in it and very deep. You don't hold the architect responsible for the satisfactory condition of a house. I have seen many an architect worry over plans. The owner comes in—the man wants to build a home—he never built anything before. His mind is centered around that particular house. "That is my house," he says, "and I cannot spend more than $10,000." The architect makes a sketch. "That is not as fine a house as that of Jones'." "But Jones spent

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$27,000." "That is what I hired you for. Can't you show me how to do it?"

Don't leave the owner out of your consideration in this matter. It is a three-party affair.

Mr. Munroe: I differ with Mr. Jellett concerning the owner. The owner cannot expect that a heating contractor will come forward and make good with his money in radiation, etc., because a designing engineer was unable to conceive or foresee the amount of radiation that would be necessary to accomplish certain results. As I said, the constructing engineer has no chance of determining the quantity of radiation necessary in the short time he has to estimate. The only other way to get around it would be a compromise between the contractor and the designing engineer, as the contractor has no right to give to the owner free, gratis, something he has not in the first place charged for, and which has not been included in his estimate. Therefore, if this responsibility has to be taken in order to get something at a reduced price or a less price, and if additional radiation is added to the building after the consulting engineer is through with his part, and after the contractor has carried out his work, and then something is lacking, then the contractor has no right to give the owner a thousand feet more or less radiation free of charge which he could have put in when the building was constructed. Therefore, the party that lets the contract, either the consulting engineer or owner, will have to take what is called for on the plans, buy what he wants to buy and get what he wants by paying for it, and not make the contractor give him something for nothing in the end. That is the whole situation. He compels the contractor to give something for nothing in the end.

It has been said here that the contractor should not be required to guarantee the consulting engineer's pipe sizes. When a man is estimating on a building he has time only to make up an estimate. If he gets the contract, then he has plenty of time to look over the plans and specifications and see for himself that the layout is one he can go ahead and risk his money in. Any changes required in pipe sizes as laid out are very slight in cost. When a man has been awarded a job he then has time to see and know what he is doing, whereas when estimating he has time only to estimate on and not verify what he is estimating on.

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Mr. Jellett: Where we make the plans and specifications we require a man to furnish labor and material and guarantee only workmanship and material. He has nothing to do with guaranteeing the design of the apparatus, sizes of apparatus or results to be obtained. Absolutely nothing. In this particular case I instanced, where I issued a certificate to the contractor, he had complied with the terms of his contract fully. I stated I knew that building was not heated to the requirements called for by the committee that had the building in charge. They wanted it heated to a certain degree. It has not been done. The temperature is below the point they desire. The contractor is in no case responsible for it.

Mr. Munroe: Your decision is a very fair one.

Mr. Jellett: There are a number of legal decisions on that point—not simply a question of policy on the part of the contractor. I know of cases where the courts have ruled that the contractor cannot be required to guarantee results to be obtained from plans and specifications furnished him. There was a case outside of New York where plans and specifications called for the construction of a steel bridge, that upon the completion of this bridge it should stand a test of so many tons per square foot and show a deflection of not more than so many inches. It was constructed according to the plans and under the supervision of the county's engineer. The county rejected the bridge. The contractor took the matter into court and the court ruled, and was sustained by the Court of Appeals, that the contractor should not be required to guarantee the figures of the engineer. If he put in the material called for by the plans and specifications in a workmanlike manner, under the supervision of the county's engineer, his responsibility as to what that bridge would carry stopped and he was in no way responsible.

The same thing happened in New York City in reference to the basement of a school, a private school, I think, up in the Bronx. I was told there was a guarantee there in the specifications in the matter of making it water-tight. The requirements specified the thickness and foundation of the walls, that they should be water-proof, the method of doing it, and under certain inspection. The cellar leaked like a sieve and the owners refused to pay for it. They went to court and, finally, to the Court of Appeals and it was decided that if the owners employed a com-

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petent engineer the contractor should not assume the responsibility. That is common law and common sense. It stands everywhere where you choose to make a test of it.

Mr. Franklin: A point I wish to call your attention to, and that is that the consulting engineer represents the owner. So far as the contractor is concerned the consulting engineer is the owner and is supposed to carry out the wishes of the owner and do as he wants. The contractor is not able to reach the owner. If he went to the owner he would have no audience, because the owner would say: "Jellett is my consulting engineer and I know nothing about it." The owner, of course, is a party to the transaction, yet, so far as the contractor is concerned and the consulting engineer is concerned, the consulting engineer represents the owner and the contractor has no voice with the owner.

President Snyder: The point made by Mr. Jellett has, I think, been carried into the courts in every state in the Union. One of the most famous decisions is that in reference to the Fifty-fourth Street Court House in New York. One of the provisions of the contract was that the cellar was to be built in a particular manner, which was clearly specified, and, further, was also to be guaranteed water-tight. The contractor erected the building according to specifications, but the cellar was not water-tight. The court decided that the contractor could not be held both to build according to specifications and also to guarantee results.

In order to cover this point the Corporation Counsel of the City of New York has requested the Heads of Departments to insert in specifications a clause, that if the contractor is not satisfied that the requirements of the specifications will result in making the guarantee possible, then he shall submit with his bid a brief statement of such changes as he desires to have made therein that will enable him to give the guarantee required.

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# TRANSACTIONS

OF THE

# SEMI-ANNUAL MEETING,

Milwaukee, Wis., July 18 and 19, 1907.

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# CLXXVII.

## PROCEEDINGS OF THE SEMI-ANNUAL MEETING.

Held at Hotel Pfister, Milwaukee, Wis., July 18 and 19, 1907.

## PROCEEDINGS.

FORENOON SESSION, Thursday, July 18, 1907, 10 o'clock A. M.

The convention was called to order by President C. B. J. Snyder.

Mr. Warren S. Johnson of Milwaukee then introduced the Honorable Sherburne M. Becker, Mayor of Milwaukee, who made an address of welcome to the city, which was responded to by Mr. Johnson.

President Snyder: The convention will now proceed to the consideration of the business before it.

The members will be glad to know the financial condition of the Society at the present time and I will therefore read the following:

FINANCIAL REPORT.

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|---|---|
| Cash on hand | $2,232.95 |
| Unpaid dues | 1,140.00 |
| Dues from new members | 185.00 |
| Total | $3,557.95 |

In addition to this there are on hand bound copies of the proceedings of a total value of something slightly over $5,000.

The proceedings for 1906 have been edited and are now ready for the press, and we shall require about $2,000 in hand to defray the expense of printing the proceedings of 1906 and 1907.

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We have but a few volumes of the earlier sessions on hand. They are becoming very rare. I think, for instance, there are only fifteen volumes of the first year's proceedings in the hands of the Secretary, and when they are exhausted they cannot be replaced.

It is becoming more and more recognized that the bound proceedings of the Society are a valuable working library. One of the members made the remark that he would not take $1,000 per volume for any which he could not replace.

The growth of the Society is something for which we can congratulate ourselves. Organized January, 1895, we now have 293 members, distributed among ten foreign countries and twenty-seven states of this Union. There is a growing sentiment that the strict requirements for admission of new members might be somewhat modified, but on this point there is much to be said on either side. The best evidence that we are not at the present time far wrong is the almost phenomenal growth of the Society. The junior members have taken an increased interest in the work and a number of them have already made application for advancement. It would be just as well for the members, in handing out the blank applications for membership among their friends, to remember the young men. There are many who are rather diffident in making their applications, but in time they will be the timber from which the Society must build.

Secretary Mackay reported the following persons elected to membership in the different grades since the last meeting:

| | |
|---|---|
| Robt. L. Claypool | Member. |
| Jay B. Dill | " |
| I. H. Francis, Jr | " |
| Thos. E. Gildea | " |
| Wm. S. Hemingway | " |
| Jas. M. Kent | " |
| Conway Kiewitz | " |
| Wm. S. Moffett | " |
| Hugh S. Morrison | " |
| Everett N. Murphy | " |
| Chas. E. Scott | " |
| Louis H. Wheeler | " |
| Edgar C. Wiley | " |

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A. S. Armagnac.....Associate.
Harry H. Hess..... "
Chas. A. Smith..... "
W. S. Fox.....Junior.
John E. Ulrich..... "
M. D. Woodling..... "

Secretary Mackay then called the roll of members and stated that a quorum was present.

President Snyder: I will now call for reports of committees, if the Secretary has any such reports.

Secretary Mackay: No reports have been handed in, but I understand that the Committee on Hot Water Data, of which Mr. James Mackay is chairman, has some addition to their report which was handed in at the annual meeting and some copies of which I have. It was ordered at that time printed and distributed to the members. That has been done and the object of any further report at this time is to prepare, as I understand, a final report for the next annual meeting.

Mr. James Mackay: The report that we have is simply a supplementary report that was submitted at the annual meeting. Mr. Capron will read the report, giving the test of an apparatus that had been installed and tested.

Mr. Edmund F. Capron (Chicago): Mr. President, we are putting some figures on the board now.

President Snyder: While Mr. Capron is preparing his figures on the board we might have this paper on "Heating and Ventilating Cars," by Mr. E. R. Swan, Cedar Rapids, Iowa, and we will lose no time.

Mr. Swan presented the paper, which was discussed by Messrs. Lewis, J. D. Hoffman and Chew.

President Snyder: I would like to say that at the beginning of the afternoon session we will have a report from the Illinois Chapter, which, I think, you will all find very interesting.

Mr. Capron then presented the preliminary report of the Committee to Secure Data on Hot Water Heating. It was discussed by Messrs. Donnelly, Lewis, Allen, Dougherty, James Mackay, G. D. Hoffman, Chew and Secretary Mackay.

President Snyder: Mr. Hale is here and I would like to have him make the report of the Illinois Chapter before we adjourn.

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(Mr. John F. Hale of Chicago thereupon read the report, as follows:)

## REPORT OF THE ILLINOIS CHAPTER.

Chicago, Ill., July 16, 1907.

Mr. President and Gentlemen: In 1905 certain members of the American Society of Heating and Ventilating Engineers, residents of the State of Illinois, formed a committee to entertain the Society at a Summer Meeting, and when this same committee came together in 1906 for a like purpose it was decided to form a local chapter if the parent body would permit.

Application was made by fourteen local members to the Board of Governors on July 9, 1906, during the Summer Meeting held in Chicago, and the question was subsequently voted upon, the result being in favor of certain changes in the constitution and by-laws relating to the subject.

On December 3, 1906, nine members of the Society, residents in Chicago, Illinois, met and formed the Illinois Chapter. The officers for the year 1907, elected at that meeting, were as follows:

President.....T. J. Waters.
Vice-President..... James Mackay.
Secretary.....John F. Hale.
Treasurer.....August Kehm.
Directors, George Mehring, Edmund F. Capron, Samuel R. Lewis.

The Chapter was incorporated on March 5, 1907, and, although other members of the Society were entitled to become charter members of the Chapter, only seventeen responded to the call, these being as follows:

W. L. Bronough.....1903
Edmund F. Capron.....1903
James H. Davis.....1899
Willard B. Graves.....1906
John F. Hale.....1902
August Kehm.....1901
Samuel R. Lewis.....1905
Jas. Mackay (Charter member A. S. H. & V. E.)

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D. F. Morgan.....1906
Geo. Mehring (Charter member A. S. H. & V. E.)
N. L. Patterson.....1905
William A. Pope.....1906
James M. Stannard.....1906
T. J. Waters (Charter member A. S. H. & V. E.)
Robert A. Widdicombe.....1903

*Associate.*

John K. Allen.....1903
John Boylston.....1906

The Chapter holds monthly meetings from October to May of each year and arrangements have been made for the use of the Meeting Rooms of the Western Society of Engineers in the Monadnock Block, Chicago. We have the use of their extensive library and reading-room, as well as the meeting room once a month. They also place at our disposal a lantern for reproducing views of buildings, apparatus or drawings for the purpose of illustrating any papers that may be read from time to time.

At the five regular monthly meetings which were held this year the attendance has been very satisfactory and the prospects are favorable for a successful season this Fall and Winter.

The American Society of Heating and Ventilating Engineers have forty-three members resident in the State of Illinois, twenty-three of whom have identified themselves with the Chapter, and we have expressions from most of the others to the effect that they will join us in the Fall.

The meetings held so far have been instructive and profitable, four papers having been presented, as follows:

First: Reading and explanation of data relating to Hot Water Heating and Boilers, by Messrs. Samuel R. Lewis and E. F. Capron, members of the original committee.

Second: Description of an extensive heating and power plant designed and installed by Mr. August Kehm. Original working plans used to illustrate the talk.

Third: Illustrated talk by Mr. E. F. Capron, entitled "Unusual Gravity Return Steam System."

Fourth: Description of an overhead hot air system, unique in

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its construction and containing features that should be of interest to all, although relating to furnace heat.

The Committee on Compulsory Legislation has done some excellent work, having met many times and drawn up a bill, which was presented to the last General Assembly of the Illinois Legislature, but, unfortunately, it was impossible to have it brought to the third reading. We have every assurance, however, that the bill will be favorably considered when the Legislature next meets, as it is generally understood that the motive behind the bill is the same as in the case of other states having similar laws, that is the proper ventilation of all public buildings and institutions.

Mr. Hale: The bill before the Legislature reached a third reading, but it was so late in the day that they finally decided that they had not time to pass all of the bills, so they put this off until the next Legislature. There does not seem to be any reason why the bill should not pass; everything seems to be in its favor and we hope for success next time.

The Committee on Compulsory Legislation has done excellent work and they should be commended for the way in which they have gone into the matter. They made a number of trips to Springfield and the lack of success was not due to any fault of theirs.

(Recess until 2 o'clock P. M.)

## Thursday Afternoon Session.

On the return from a trip to the H. W. Johns-Manville Company's plant, which practically all of the members and the ladies made in automobiles, followed by a buffet luncheon in the city offices of the company, President Snyder called the meeting to order at 3:15 P. M.

President Snyder: The first matter this afternoon is a paper on "Heating and Ventilating a Group of Public Schools," by Samuel R. Lewis.

Mr. Lewis read the paper and it was discussed by Messrs. Allen, G. D. Hoffman, Larsen, Donnelly, James Mackay and W. M. Mackay.

Vice-President Mackay (in the Chair): We will now pass to the next item on the program, which is a paper by Professor

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J. D. Hoffman, "The Design of a Plenum System of Warm Air Heating for a School or Office Building."

The paper was presented by Professor Hoffman and discussed by Messrs. Allen, Lewis, Larsen, Donnelly and Chew.

Topics Nos. 1, 2 and 3 were then presented for discussion, as follows:

Topic No. 1. "The relative efficiency and velocity in two air pipes, one having a vertical rise of 18 inches to a round elbow supplying a pipe running horizontal for 10 feet, the other having a uniform upward inclination of 18 inches in 10 feet."

Topic No. 2. "The difference in capacity to be provided in warm air pipes where air travels at different velocities."

Topic No. 3. "The relative size of hot air pipes carrying the same volume of air at velocities of 100, 150, 200 and 300 feet per minute."

The topics were discussed by Messrs. G. D. Hoffman, Chew, Donnelly, James Mackay, W. M. Mackay, Larsen, Folsom, Lewis and Snow.

The "Steam Loop" was then discussed by Prof. J. D. Hoffman and Messrs. Donnelly and Snow.

At 5:45 P. M. the meeting adjourned until 10 o'clock A. M., Friday, July 19, 1907.

## Forenoon Session, Friday, July 19.

President Snyder called the meeting to order at 10:30 o'clock.

President Snyder: Gentlemen, Mr. Hoffman is here now and we will open the morning's session with his paper on "The Combined Pressure and Vacuum System of Steam Heating."

The paper was read by Mr. Hoffman and discussed by Messrs. Snow, G. D. Hoffman, Capron, Weinshank, Donnelly, Kinealy, Johnson, Bull, Davis and Larsen.

President Snyder: Yesterday we were discussing the flow of air in pipes, etc., and we touched upon air washing. We were asked to defer that subject until to-day. If it is the wish of the body that we take up the subject of air washing as a subject for discussion, a motion to that effect will be in order.

Upon motion the subject of air washing was made the order for the Friday afternoon session.

On motion the meeting stood adjourned until 2 o'clock P. M.

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## AFTERNOON SESSION, Friday, July 19.

The meeting was called to order by Vice-President James Mackay at 2:30 P. M.

Vice-President Mackay: This morning it was decided to take up the subject of air washing, but in doing so you must not forget the other topics.

On motion of Mr. Chew it was agreed to proceed with Mr. Schlemmer's paper.

Mr. Schlemmer presented his paper and it was discussed by Messrs. Widdicombe, Kinealy and Allen.

The subject of air washing was then discussed by Messrs. Chew, Kinealy, Allen, Weinshank, Dougherty and Snow.

(At this time President Snyder took the chair as Chairman of the meeting.)

President Snyder: I will read the Topic No. 4. "The amount of radiation necessary to maintain 70 degrees in a building having movable glass and an excessive air leakage and in one having weather strips practically avoiding air leakage."

If no one desires to speak on that point we will pass to No. 5, "The chemical and physical properties of cast iron used in boilers and radiators."

The topic was discussed by Messrs. Chew, James Mackay, Allen, Bull, W. M. Mackay, Weinshank and Kauffman.

Topic No. 6, "The relative advantage of a wet or dry return to a boiler set at the end of a long, narrow building in a gravity system, and the advantage of extending the main a long or short distance beyond the last radiator connection," was discussed by Messrs. W. M. Mackay, Donnelly and Weinshank.

Topic No. 7, "The benefits derived from the use of fusible plugs in cast-iron steam boilers," was discussed by Messrs. W. M. Mackay, James Mackay and Kinealy.

Topic No. 8, "The advantages in efficiency and economy of one large or two smaller boilers for carrying the same large amount of radiation, assuming in either case ample capacity for the work," was discussed by Messrs. W. M. Mackay, Donnelly and Snow.

Topics Nos. 9 and 10, "The comparative fuel consumption of firebox boilers in brick setting and horizontal tubular boilers," and "The size of standard firebox boilers which should be pro-

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vided to supply 1,500 pounds of steam per hour for direct radiation at three pounds pressure, burning hard coal with a 60-foot chimney and good draft," were discussed by Messrs. Lewis, Larsen and Snow.

Topic No. 11, "The use of recirculated air in furnace heating," was discussed by Messrs. Oldacre, Chew and Snow.

President Snyder: The hour for adjournment has arrived. It is with great regret that I am obliged to declare this meeting adjourned. I know of none other that has been so interesting or in which the interest has been so fully sustained from the beginning to the hour of adjournment. I desire to thank you all for your attention and the interest displayed, and trust that as many as can be there will be at the meeting in January.

### VOTE OF THANKS TO THE MILWAUKEE MEMBERS.

Mr. Capron: Before we adjourn, I think it is in order to extend a vote of thanks to our Milwaukee members for the entertainment given to ourselves and ladies.

Upon motion by Mr. Capron, duly seconded and carried, the thanks of the Society were extended to the Milwaukee members for their entertainment, etc.

President Snyder: I hope that sentiment will find further expression at the banquet later in the day, and that is the reason I postponed it, but it is as well to have it in our proceedings now.

On motion, duly seconded and carried, the meeting was adjourned *sine die*.

List of Members and Guests present at Semi-Annual Meeting, July 18 and 19, 1907:

### MEMBERS.

ALLEN, JOHN K.
ALLEN, JOHN R.
BOTTUM, GEO. L.
BRENNAN, JOHN S.
CAPRON, E. F.
DAVIS, JAS. H.
DONNELLY, JAS.
DOWNEY, WM. K.
FOLSOM, CHAS. G.
GETSCHOW, GEO. M.
GORDON, E. B., JR.
HALE, JOHN F.
HOFFMAN, GEO. D.
HOFFMAN, JAS. D.
JOHNSON, WARREN.
KAUFFMAN, SAM'L.
KEHM, AUG.
KINEALY, JOHN H.
KIRK, GEO. H.
LAMB, FOSTER W.
LARSEN, L. A.
LEWIS, S. R.
MACKAY, JAS.
MACKAY, W. M.
MARTIN, J. H., JR.
MURPHY, E. N.
NEILER, S. G.
NEWPORT, CHAS. F.
OLDACRE, C. E.
PATTERSON, W. S.
RYAN, EDW. J.
SCHLEMMER, O. H.
SNOW, WM. G.
SNYDER, C. B. J.
SPEAR, J. J.
STANNARD, JAS. M.
SYMMS, CHAS. D.
WATERS, T. J.
WEBSTER, WARREN.
WEINSHANK, THEO.
WIDDICOMBE, R. A.

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## GUESTS.

AINSWORTH, A. A.
BACKLIN, C. F.
BARD, F. N.
BASS, F. H.
BIERSACH, P. L.
BOGART, P. B.
BOGENBERGER, JOHN.
BRAEMER, W. G. R.
BROWNELL, C. D.
BRUCE, W. G.
BUSH, W. K.
BULL, STORM.
CHATHAM, RALPH.
CHENOWETH, W. H.
CREMER, DR.
CRIPPS, A. G.
DOESBURG, J. M.
DOUGHERTY, P. J.
DRURY, L. H.
DURR, W. E.
ELLIS, H. W.
GREEN, WM. H.
HALSEY, W. H.
HOLLAND, J. E.
HINES, IRWIN.
JOHNSON, P. F.
JOGERST, J. P.
KAUFFMAN, F. W.
KEENEY, F. P.
KENNEDY, D. E.
KIEWITZ, CONWAY.
KRUSE, C. B.
LADE, RUD.
LAMB, C. G.
LEACH, H. J.
LOWE, C. A.
LINDERMANN, W. C.
MACNICHOL, F. F.
MCCAY, J. R.
MCLELLAND, H. B.
MILLER, C. W.
MORRIS, J. C. C.
MOSS, H. S.
MUELLER, L. J., JR.
NICHOLS, GEO. W.
PATTERSON, O. K.
PHELEY, F. G.
PITTELKOW, A. G.
RICHARDSON, W. H.
RIEMER, L. N.
RIGBY, E. D.
SPRINKMAN, F.
SWAN, E. R.
TRATMAN, E. E. R.
TUPPER, C. A.
VANAUKEN, B. E.
WARG, R.
WATROUS, P. B.
WEHR, CHAS. E.
WINSLOW, E. F.
YOUNGLOVE, C. H.

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## CLXXVIII.

# HEATING AND VENTILATING OF CARS.

BY E. R. SWAN.

(Non-member of the Society, presented by request.)

The heating and ventilating of cars has received but little attention from those versed in the science of ventilation. What little has been done appears to have been by persons of no experience or knowledge of the principles that must be applied in order to secure it. Heating and ventilating has not been considered as a science of itself, and yet it is one of the most difficult problems in engineering.

Dr. Dudley, Chemist, who designed the system of ventilating used on the Pennsylvania Railway, in writing upon the subject, says, in part: "It seems not improbable that if a vote of the general travelling public could be taken on the question as to what improvement or change in passenger cars at the present time would most conduce to the comfort of passenger travel, a very large majority of the ballots would be in favor of an improvement in car ventilation.

"It is to be confessed that the discomfort attendant on riding a number of hours in a stuffy, overheated passenger car and especially the annoyance and discomfort from spending the night in an overheated, ill-ventilated sleeping-car, are so great that it is not at all surprising that not only individual passengers but also technical papers, and indeed the general press of the country, should from time to time break out into a tirade against the present condition of ventilation of passenger cars. Few problems in engineering have ever been undertaken which are so fraught with difficulties as the ventilation of cars on railroads. To supply them with the proper amount of fresh air throughout the year, and at the same time to exclude from them objectionable matter, such as smoke, cinders and dust, are certainly difficulties enough. The shape of the car itself, the very small

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space compared with the large number of people, the question of keeping people warm, and the exclusion of objectionable matter from them, each one of these items is a problem in itself, sufficiently difficult to tax the skill of the best experts, and, when all combined in one, it is little wonder, apparently, that progress has been so slow.

"Is it necessary to ventilate cars both winter and summer? It would naturally be expected that the doors and windows would be sufficiently satisfactory sources of fresh air in the summer season, and that, therefore, it would only be necessary to study the subject of car ventilation for the winter.

"Unfortunately, part of the problem, as already stated, is to exclude objectionable matter coming from without, and on dusty roads it is absolutely essential, even in warm weather, to keep the doors and windows closed on account of dust. Furthermore, smoke and cinders from the locomotive not infrequently are annoying even in the summer season, so that it seems fairly probable that a good system of ventilation should be operated both in winter and in summer. It has been urged in the technical press, and in conversation with would-be experts, that it is an easy matter to ventilate cars; simply let air in and provide places for the foul air to get out. I am compelled to say that I think this is a very unsatisfactory view of the case. In this climate it is unendurable to let fresh air into cars in proper amount in the winter season without warming it, and consequently it is perfectly clear that studies on ventilation must at the same time take into account the heating system of the car. Some systems of car ventilation, if they may be called systems, are little more than apertures in the car, and some so-called systems simply attempt to exhaust air from the car without providing inlets. So far as my knowledge goes, the experience with these systems is that neither of them can be used for any length of time; one can stand a little cold air for a few minutes, but when we come to consider the amount of air required, it is little short of an absurdity to attempt to ventilate a car without at the same time warming the air."

True and successful ventilation consists in the free access of warm, pure air into the car, and the escape of bad or vitiated air therefrom. If the air is filled with dust, smoke and other objectionable matter, it cannot be said to be pure, and it must

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be excluded. Cold draughts must be avoided, and a constant volume of fresh air supplied without fluctuation. Economy of operation is important, but must not be at the expense of efficiency.

The first attempt at improvement in the ventilation of cars was with the deck which was put on the car for that purpose. This was before there were any systematic studies made of the subject of ventilation. While it is impracticable, the railroad companies appear to be unwilling to give up the idea, and nearly every attempt made to improve the ventilation has been done in connection with the deck, and no attempt is made to warm the air before it enters the car. The deck could very well be omitted from the car so far as ventilation is concerned, as the ventilation of a car through the deck windows or any contrivance to be used in place of them is a fallacy, as the entering or outgoing air depends wholly upon the direction and velocity of the wind. If the windows are open, the air will enter only on the windward side and escape on the leeward side. Whether it will descend downward into the main body of the car will depend not only upon the difference in temperature of the interior and exterior, but upon the velocity at which it enters the car. The windows are hinged at the bottom and swing inward, and the entering air is deflected upward and across the ceiling until it meets resistance, when it will descend against the leeward window which will deflect it out of the car. As shown in Fig. 1,

FIG. 1.

some small portion will descend to the floor and be drawn across the feet and through the filth that may be on the passengers' shoes or the floor to the heaters, and when warmed pass upward to the breathing line loaded with impurities from the breath, persons and floor. The wire filter placed over the window openings, unless carefully attended to and cleaned, will choke up so the air cannot pass through. If the windows are closed on the

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leeward side, the cold air will descend and cause cold and unpleasant draughts, and will also cause a pressure in the car which will be governed by the velocity of entering air; when the pressure in the car is greater than the exterior windward sides, the air will be forced back through the windows and the fluctuating winds seesaw back and forth through the windows. The speed of the car will have no material effect on the entering air; it will depend entirely on the cross currents. If there are no cross currents there will be no entering air, and if there are cross currents the volume will depend upon the velocity of the cross winds.

The same things apply to summer ventilation of cars, except that the exterior and interior air will be so near the same temperature that the incoming air will not descend of its own accord, but only as it is forced down. If the windows in the lower part of the car be open for ventilation the cross currents will carry the breath of the person on the windward side directly across the face of the person sitting on the leeward side. Hence, ventilation of cars should be done by downward currents only.

If the ventilation must be done through windows, the windows should be opened at the rear end of the car on the windward side and at the front end and on the leeward side; but this will not and cannot successfully and satisfactorily ventilate a car, as the force of the moving current will cause the air to pass to the leeward side and forward to the outlet, where it will escape without thorough distribution, which is necessary for successful ventilation. No car or room can be successfully ventilated through the windows, winter or summer; windows must be closed on the windward side in case of strong winds, rain or dust storms, and only a seesawing effect will be produced through the windows on the leeward side. Hence, neither cars nor buildings should depend upon windows for ventilation.

If the windows are open in the deck it is no proof that fresh air is entering the car. The winds may be in the wrong direction, or the wire screen choked so that the air cannot pass through. The only sure proof that the fresh air is entering the car will be in the cold draughts it will cause. Usually the person in charge does not consider the opening and closing of the windows in connection with ventilation, but to control the temperature. If the car is too warm the windows are opened, if

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too cold they are closed. No system of ventilation can be a success unless the air is warmed before it enters the car. It will not cost as much to warm the air before it enters the car as it will to warm it after it is in the car. It is a well-established fact that more air can be warmed by passing it over the heaters reasonably fast than at a slow movement. John P. Fox, a railway engineer, says that, according to a test made by the street railway company, it took 35 per cent. less current to heat a car, if some of the current were diverted to a fan blowing outside air through the heaters.

No car ventilator which is placed in the side of the deck or which does not warm the air before it enters the car is worth considering. The only one that we know of that has any claim to merit is the Dudley system. (See Figs. 2 and 3.) Pure air

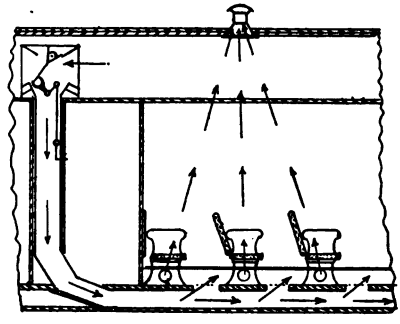

FIG. 2.

is taken in through two hoods at diagonally opposite corners. This air is conducted downward to longitudinal open spaces underneath the car. Through these spaces the air passes until it reaches apertures through the floor, whence it flows upward over heated steam pipes and out into the body of the car through large tubes placed under each seat. The foul air is removed through several ventilators placed on the roof of the car, the air supply is controlled by opening and closing the ventilators. While Dr. Dudley does not apply the principles used by the heating and ventilating engineers in using the upward system of ventilation, and the control of the volume is in the outlets instead of the inlets, it is, however, far ahead of the other so-called systems. Both the inlets and outlets should be operated to secure good results. While Dr. Dudley recognizes the importance

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of excluding dust and smoke from the car, he has made no provisions to prevent it.

If we have successful ventilation, the fresh air *must* be warmed

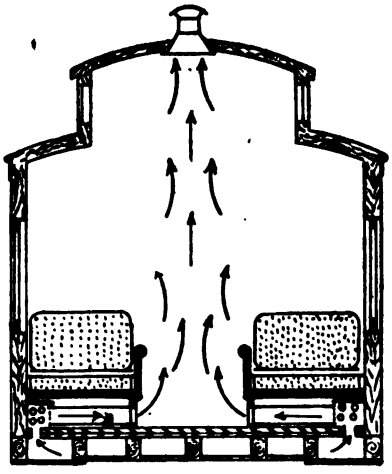

FIG. 3.

before it enters the main body of the car, and this can be done only with some system of indirect heating, and the volume of air required will be governed by the proper location of the inlets and outlets. A large volume of air may be admitted into the car, and, if allowed to escape without proper circulation, very little benefit will be derived and much fuel wasted. Let us quote from "Heating and Ventilation of Buildings," by Professor Carpenter, Past President of American Society of Heating and Ventilating Engineers and Professor of Experimental Engineering Cornell University: "The introduction of pure air can only be done properly in connection with the system of heating, and any system of heating is incomplete and imperfect which does not provide a proper supply of fresh air. The advantages of introducing warm air at or near the top of the room are, first, the warmer air tends to rise, and hence spreads uniformly under the ceiling; second, it gradually displaces other air, and the room becomes filled with pure air without sensible currents or draughts; third, the cooler air sinks to the bottom and can be taken off by a ventilating shaft."

So far as the system introduces air at the top of a room, it

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is forced distribution, and produces better results than other methods. When the inlet is placed in the floor, or near the bottom part of the wall, it is a receptacle for dust from the room, and a lodging place and breeding place for microbe organisms. "The outlet for foul air should be as near the bottom as possible."

Mr. Joseph A. Moore, Inspector of Public Buildings for Massachusetts, and who has been engaged for the past twenty years supervising and testing heating and ventilating of school buildings, after inspecting and experimenting on hundreds of buildings, says in his volume "The School House":

"In cold weather the fresh air must be warmed to a number of degrees above the temperature at which we wish to have the room at the breathing line. Heated air will go to the top of the room, no matter where we admit it, and its distribution will begin there. By leading it there in pipes or flues we avoid carrying up dust and foul air with it, and we can locate the inlet and direct the flow of air so as to distribute it more evenly than if we admit it at the floor. The air will spread over the ceiling, the falling current, caused by cooling, descends to the floor, and may be best taken out at the bottom of the room. If the air is admitted at the floor and taken out at the ceiling, there is established a current between the inlet and the outlet, leaving the foul air in some parts of the room almost unmoved, and only slowly and partly drawn into the current, and the great loss of heat necessitated thereby calls for the consumption of a much greater quantity of fuel. The hot air is drawn off rapidly from the top, while the cold air remains at the bottom of the room. A school-room supplied with 1,500 cubic feet of air per minute, with properly located fresh warm air inlets and foul air vent flues, will have the air at the breathing plane kept as pure as it will be when supplied with 2,500 cubic feet per minute, with no proper provision for circulating the air.

"The economy of heating and forcing this extra 1,000 cubic feet of air into a room has never been satisfactorily explained."

Professor Carpenter and Mr. Moore are certainly experts in heating and ventilation. While they treat on the subject of ventilation of buildings, the same principles must be applied to cars for successful ventilation.

We do not purpose to advocate any particular standard of purity, but will leave that to the medical profession to deter-

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mine. The quantity of air required will depend upon circumstances. When many persons are confined in a small space, like a car, not as much fresh air will be required as in a large space, where the foul air diffuses with the fresh air before its removal.

The tendency of a person's breath is downward, and by bringing in the warm air at the top of the car and removing it at the bottom, the air, as it descends to the breathing line, is all fresh, and as soon as we introduce sufficient air into the car to maintain a downward current it will not matter whether there are 30 or 60 passengers in the car, they will have pure air to breathe, the air will not be contaminated in the least; the diffusion of the gases take place slowly, and before it can diffuse upward to above the breathing line it will have passed out of the car. Some writers claim that the tendency of the breath is upward. I cannot see how this can be. When the air is expelled from the nostrils it is started downward; now what is there to cause it to rise except as it diffuses with the air: there is not enough difference in temperature between the expired air and the air in a warm car to cause it to change its course in an upward direction. If this is true, why need we put in such a large volume of air? Is it not enough if we maintain a downward current of air? I am not taking into consideration the vitiated air from lamps, that we know flows upward on account of the extreme heat, and is started upward at a rapid velocity, and should be removed from the car independent of the ventilating system. In ventilating cars or buildings, two important matters must be taken into consideration. Under ventilation, which is at the expense of health, and over ventilation, which is at a money expense, both should be guarded against. Every cubic foot of air heated above that which is required for ventilation is at a money loss. If we heat 2,000 cubic feet of air when only 1,000 cubic feet is required, the extra expense for fuel will be doubled. Fluctuations are more liable to occur in cars owing to the variable changes in speed than in buildings, but in winter weather larger variations are bound to occur, and there will be but very little time in either cars or buildings but what there will be either under ventilation or over ventilation if the apparatus is controlled by hand. It is utterly impossible to regulate the air supply by hand. A man may have only one inlet to look

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after, and nothing else to do, and he cannot prevent fluctuations. The only thing he can do is to guess at it. If he is a good guesser he will come nearer than would a poor guesser. Hand regulation is all guesswork.

There is only one way to prevent fluctuations and waste, and

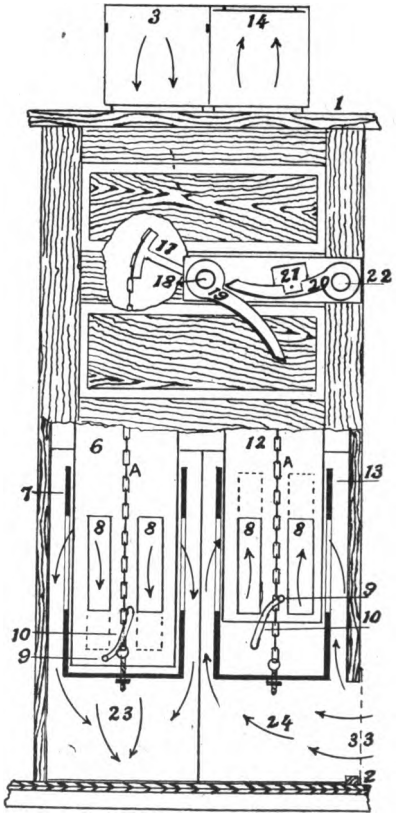


FIG. 4.

that is automatic control of the air supply. Figs. 4, 5 and 6 show a system designed by the writer for an automatic control of the air supply and the inlet and outlet for car ventilation. Fig. 7 shows automatic control for the air supply to buildings. Fig. 4 is a vertical end view, with the lower portion of the casing removed. Fig. 5 is a vertical side view with the casing removed. Fig. 6 is an automatic outlet for foul air. The numerals refer to the same parts in either figure.

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In describing the devices and referring to the drawings, numeral 1 designates the top of the car, and numeral 2 the bottom of the car.

The apparatus is arranged between the top and bottom of the

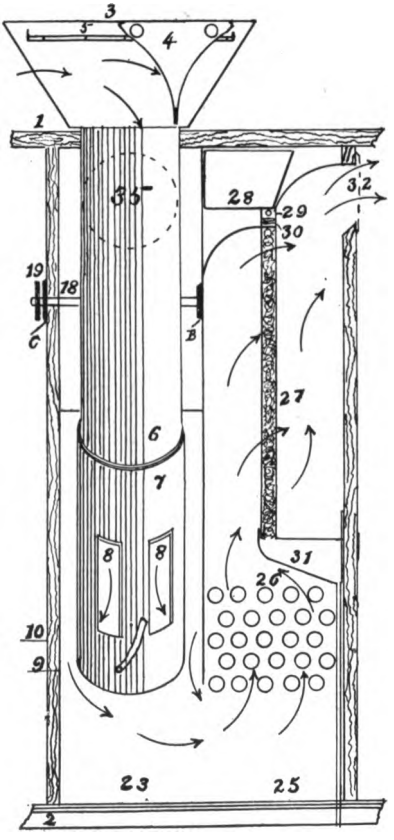


FIG. 5.

car at either end. In a combination car it can be located at the partition, and will heat and ventilate both compartments with the one apparatus.

Numeral 3 is the intake for fresh air located on top of the car; numeral 4 is an automatic movable valve, which moves on track 5 located on the inner side and near the top of 3; 6 is the downtake pipe, opened at the lower end and provided with a plurality of vertical openings or slots (Fig. 8) near the lower end.

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The passage of air is governed by valve 7, which is mounted for movement longitudinally and rotary, and which receives the lower portion of pipe 6. 7 has corresponding openings, as in

FIG. 6.

6, and registers therewith. The openings in 6, however, are somewhat longer than in 7, in order to maintain the same vertical length in slots 8 when 7 is forced downward by the pressure of the inrushing air. The rotary movement is produced by pin 9, which is attached to pipe 6, and extends outward through

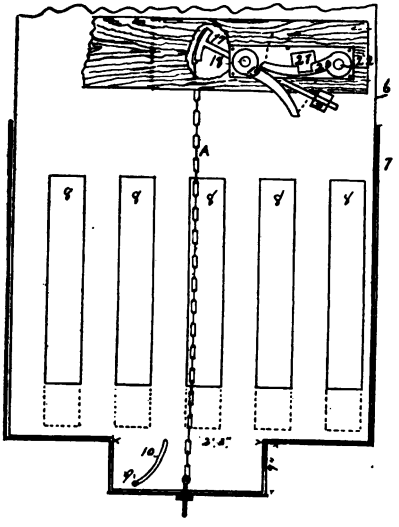

FIG. 7.

the spiral slot 10. Pipe 12 and valve 13 are constructed in the same manner. Pipe 12 is the foul air outlet, and has connection with 14, in which is located two automatic dampers 15 connected by rod 16.

Valves 7 and 13 are connected to a cross arm 17 by a flexible connection "A." 17 is firmly attached to shaft 18, which operates in suitable bearings "B" and "C." Valves 17 and

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13 being attached to opposite ends of lever 17 balance each other. The downward movement of valve 7 causes an upward movement of valve 13.

An important feature of the apparatus is the special means utilized in order that the quantity of air admitted to the car may be certain and not subject to variation, due to the variation in the speed of the car. To accomplish the above peculiar regulating mechanism for governing the movement of the valves 6 and 13 is employed. This regulating mechanism includes the arm 19, attached to the end of the shaft 18 for movement therewith, and curving outwardly and downwardly from said shaft. Arranged to connect with the upper surface of the arm 19 is a weighted lever 20, which is pivoted at one end, as shown at 22. 21 is an adjustable, slidable weight, the position of which may be fixed with a suitable set screw. The coöperation of 19 and 20 is as follows:

Normally, the outer end portion of the lever 20 bears against the arm 19 near the point of connection of the latter with shaft 18. When the car begins to move the amount of fresh air passing down the fresh-air flue 6 increases in direct ratio to the increase in the speed of the car; on the increase of the velocity of the air passing into the flue 6, the increased pressure due to the increased velocity of such air, with regard to valve 7 is resisted by the regulating means, for the reason that the connection "A" between the valve 7 and the lever 17 begins to pull downwardly on said lever, thereby gradually raising the arm 19 and gradually causing the inner end of the lever 20 to approach the outer end of said arm 19.

As the point of contact of the lever 20 approaches the outer end of the arm 19, it becomes obvious that said lever 20 obtains a greater leverage with respect to the arm 19, and the weight brought to bear on arm 19 gradually increases, due to the increased velocity of air pouring into the flue 6, causing a gradual downward movement of valve 7, which movement is retarded and is resisted by a gradual increasing weight connected with the valve for that purpose. As the area of the opening 8 decreases, as the velocity of the air in flue 6 increases, the quantity of fresh air passing into the car will be certain, with no fluctuation of the fresh air.

The quantity of foul air withdrawn from the car through the

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foul-air pipe 12 is also proportionate with the velocity of air passing into the flue 6, as the amount of suction in the passage 14 depends and is proportionate with the velocity of air. As the velocity of the air entering flue 6 decreases, because of the slowing down of the speed of the car, the pressure of air on the bottom of the valve 7 decreases and the same move upwardly, under the influence of the weighted lever 20, decreasing as the point of contact of these parts approach the shaft 18.

The valve 6 is placed in compartment 23, and valve 12 in compartment 24, the indirect heating 26, and the air washer 27 is placed in compartment 25. The air washer 27 may be of any substantial form which embodies spaced sides, between which is located the filtering material, which may be excelsior or the like. Aluminum excelsior would be preferable. The filtering material is kept in a moist condition by being supplied with water from tank 28, or by any other suitable means (from one to two gallons per hour will be required), through a small perforated pipe 29, with a suitable bib for regulating the water supply. Cotton or similar spreading absorbent substance, as indicated at 30, should be located at the upper portion of the filtering material, just below the pipe 29; said cotton or material effectively spreading the moisting fluid over the filtering material. A drip pan 31 is connected to the lower end of the filter 27, receiving the dirt washed from the air. A suitable pipe is connected to the drip pan and through the bottom of the car, through which all dirty water and filth passes out of the car.

34 is a revolving door to be used when warming up the car or when not occupied.

35 are dampers located near to top of pipes 6 and 12, to close the inlet and outlet when 34 is used for revolving the air or when passing through a tunnel.

Generally describing the operation, it will be obvious that as the car commences to move the air will pass into the intake 3, nearer the direction in which the car is travelling. The inrush of air will exert a pressure against the valve 4 and move it to the leeward side of the pipe 6, and deflect the air downward in pipe 6 to the end of the passage and exert a pressure against the bottom of valve 7, until it closes the openings 8 in flue 6 and 12 to a predetermined extent. The fresh air passes

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through the openings 8, and follows in the lines indicated by arrows through the heaters 26 and the air washer 27 into the car at 32.

While the fresh air is being admitted to the car, as above described, the foul air is being removed through the opening 33, at the floor line and upward through the openings 8 and pipe 12, and through the foul-air outlet 13 at the leeward end. Dampers 15 in outlet 14 (Fig. 6) are automatic. When the car is moving the pressure of the air on the windward damper 15 forces it downward and raises the leeward damper 15 horizontally, opening the passage to the leeward end. The fresh entering air and the outgoing foul air will be proportionate, and there will be no vacuum in the car. A slight plenum should be maintained at all times. This is very important if we wish to avoid cold draughts through cracks and crevices. The wind will have the same effect as the moving car. If the wind is moving in the same direction and faster than the car is travelling, the valves and dampers will be forced to the proper position to receive fresh air and to expel foul air, and will always maintain the air supply.

The intake, the outlet and the volume of air are automatically controlled and need no attention whatever, and it is the only ventilator that automatically controls the air supply to a certain quantity. The same amount of air will enter the car under all conditions after a speed of 10 miles is obtained. It is a combined system of plenum and exhaust, using the movement of the car for power instead of a fan. In cold weather the heaters will always cause a circulation of air, and some ventilation will always take place when the car is standing.

Fig. 7 shows the manner of construction for large air controllers. Pipe 6 and valve 7 may be of any size.

At a speed of 10 miles per hour the air pressure is one-half pound per square foot, and the slots 8 are wide open. As the speed of the car increases the slots gradually close, which reduces the air supply. When a speed of 20 miles is reached the pressure is 2 pounds per square foot and the openings are closed one-half, which allows the same quantity of air to pass as at 10 miles per hour. At 40 miles per hour the pressure is 8 pounds per square foot, and the slots 8 are closed three-fourths. At 80 miles per hour the pressure is 32 pounds per square foot,

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and the openings are closed seven-eighths of the way, and the same volume of air will pass through at any rate of speed.

It will be seen that the supply of air is under perfect control, and over ventilating cannot take place; hence, there will be a large saving in the expense for fuel. It seems to be the opinion of some that a fan will supply a constant volume of air at all times. This is an erroneous idea. If there is sufficient wind to cause a plenum in the fresh-air compartment the fan will deliver more air than when it is normal, or a vacuum in the fresh-air compartment, and there will be fluctuations of the air supply and under or over ventilation. It would be interesting to know how much is wasted by over ventilation.

It has been suggested that fans be used in car ventilation. Fans would be of no use, only when the car was moving very slowly or standing still. As soon as the speed of the car is greater than the velocity of the air driven by the fan it would be of no advantage. Usually, when the car is standing the doors are open, and thorough distribution will not take place, in any event. If the inlet for fresh air faces the direction the car is moving and the outlet toward the rear, the movement of the car will produce the same result as a fan.

It is generally considered that car ventilation is more difficult than the ventilation of buildings. We do not think that that is the case. In building ventilation there is never a fixed point to work from. The wind is changeable, and it is not known one day from what direction the wind will be next day, whether the wind will blow into the inlet or syphon the air out. With a car it is different. We are always sure of the air entering the inlet if it faces in the direction the car is moving. If the wind should blow in the direction and faster than the car is moving by using an automatic intake which changes the position of the intake to conform with the direction of the wind, we would still have an air supply passing into the car. Cross winds will not affect it, any more than the movement of the cars affects the air supply passing into the windows in the side of the car. When we have once designed a perfect system for a car it can be applied to all cars. Not so with a building. Each and every one is a different proposition. Even in duplicate buildings outside conditions and locations of buildings or trees will change the direction of the air currents, and different engineering will be required.

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The reason car ventilation has not been more successful is the heating and ventilation has not been considered a science, and the ventilating engineer has not been called upon to solve the problem, but it has been left to men who, though they may be versed in the other sciences, may know nothing of the principles of ventilation.

Whether cars will ever be properly ventilated will depend upon the operating companies or the law-makers. It can be done and the expense would be nominal. One cent for each passenger carried on the railroads for one year would ventilate every passenger car in the United States, and the saving of fuel would more than repay the expense in three or four years. It would seem that no better time could be selected to introduce ventilation upon the railroads than the present time. Hundreds of steel cars are being, or about to be, built which will not be ventilated any better than the cars now in use. While I am not an authority on car building, it would seem to me that the deck might be left off and a large saving made. The deck is of no use as a ventilator, and surely does not add to the beauty of the interior of the car. The extra cost of building the deck would ventilate a dozen or more cars. Conditions are much worse than they were before the vestibule cars were introduced, as opening the doors does not help the ventilation, but allows the impure air to drift from one car to another. More complaint is made about the sleeping cars than coaches, yet the chair cars and coaches are worse than the sleepers, for the reason that many more people are in them and the breathing space is at least 50 per cent. less. Surely the poor man or woman who is obliged for the lack of funds to ride in the coach is as much entitled to pure air to breathe as is the wealthy passenger who rides in the Pullman. Fresh air is too cheap, the supply is too large to be stingy of it, and health is too important to be deprived of it.

Is it necessary to filter or wash the air? It would seem that it would be, a part of the time on steam roads at least, in dusty weather. Dusty air must, of necessity, be a dry air. By passing it through a wet filter all dust and other impurities would be removed and the humidity greatly improved.

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DISCUSSION.

President Snyder: This paper was sent out prior to the meeting, and all the members have had an opportunity to study it.

Mr. Samuel R. Lewis (Chicago, Ill.): I believe the paper by Mr. Swan, to encourage the ventilation of cars, is a very good thing. I think all of us will admit, as a rule, that cars are very poorly ventilated. My understanding of what Mr. Swan recommends is an automatic device which will let a given volume of air in and let that same volume out. It seems to me that it would be a good idea for some of our committees, say the one on compulsory ventilation, to get something in the way of laws about proper ventilation of cars.

Prof. John R. Allen: I would like to inquire of Mr. Swan what he figures the possible velocity of air obtained in the flues or ducts used in such a car system, and what allowance is made for the variation of speed of the car in its operation; that is, under apparently slow speeds, would it be possible to acquire a sufficient velocity of air in the flues to give the car proper ventilation?

Mr. Swan: The velocity in the duct will depend upon the speed of the car up to a predetermined speed, which may be as low as eight miles per hour, with an inlet equal to one square foot. After that speed is obtained the volume can be automatically controlled. The volume will depend upon the velocity and size of intake ducts, and proper ventilation will be secured if proper sized ducts are used.

Mr. Lewis: Did you not state that, as you had tested this, it would operate on a velocity of five miles an hour?

Mr. Swan: Yes, sir, it would operate on a velocity of five miles an hour; by having the inlet twenty-seven inches in diameter, which is equal, approximately, to four square feet.

Prof. James D. Hoffman: I think Mr. Swan has touched upon a subject which should be followed up. In connection with the paper, I notice, on page 173, this statement:

"It will not cost as much to warm the air before it enters the car as it will to warm it after it is in the car."

I wonder if it would not be well if Mr. Swan would state in his paper why it would cost more one way than the other; be-

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cause we know that one heat unit passing through a radiator will heat air, if a large volume, to a certain temperature; if a small volume of air, it will heat it to a higher temperature; so that a certain heat unit will do as much under one way as it will the other; but possibly he means the mechanical difficulties in getting the air to the heater, and owing to that fact we are losing heat by the wayside. I ask for information.

Mr. Swan: I made that statement, and I believe it is true, for this reason: You can warm more air by passing it over radiators at a reasonably fast velocity than you can at a slow velocity. If you can do that, it would not cost as much to heat it.

Prof. Hoffman: I understand you mean the efficiency of the radiator is greater.

Mr. Swan: Yes, sir.

Prof. Hoffman: And the mechanical difficulties are eliminated in the way you suggest.

Mr. Swan: Yes, sir.

President Snyder: Any further discussion?

Mr. Frank K. Chew: Professor Carpenter brought this matter up in a paper at the January meeting, so that this paper is really a continuation of the subject of Professor Carpenter's paper. It is another evidence of progress in the art.

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## CLXXIX.

# HEATING AND VENTILATING A GROUP OF PUBLIC SCHOOLS.

BY SAMUEL R. LEWIS.
(Member of the Society.)

The buildings consist of a High School, a Primary School and a Grade School, all located in the same block. They are furnished with steam at 5 pounds average pressure for heating; with electric current for lighting and power; and with compressed air, for various purposes, from a common power plant located centrally, and owned by the Municipal School District. The plant is located at Galesburg, Illinois; was designed by the writer and installed by the firm he represents. The Primary School was completed a year before the High School, and was heated during that time with exhaust steam from a central plant which furnishes power for street railways and electric lights. The heating plant in this building consists of a standard blast steam equipment, with direct radiation in the toilets, offices and corridors only. This type of plant is not adapted to economical operation from a central city plant, because it is not operated twenty-four hours per day, as residences, stores, etc., heated by direct radiation would be, but, on the contrary, is in use, with the fan running, only from six to ten hours per day for five days per week. On account of cooling off every night the demand for steam on cold mornings was therefore enormous, and to supply it at two pounds pressure often necessitated a back pressure of from six to ten pounds on the large engines in the power house. The fan motor was on the railway circuit, and would cut out whenever the current weakened, necessitating constant attention by the janitor. Thus neither the School District nor the Railway and Light Company were satisfied with the conditions. In the meantime the High School was in process of erec-

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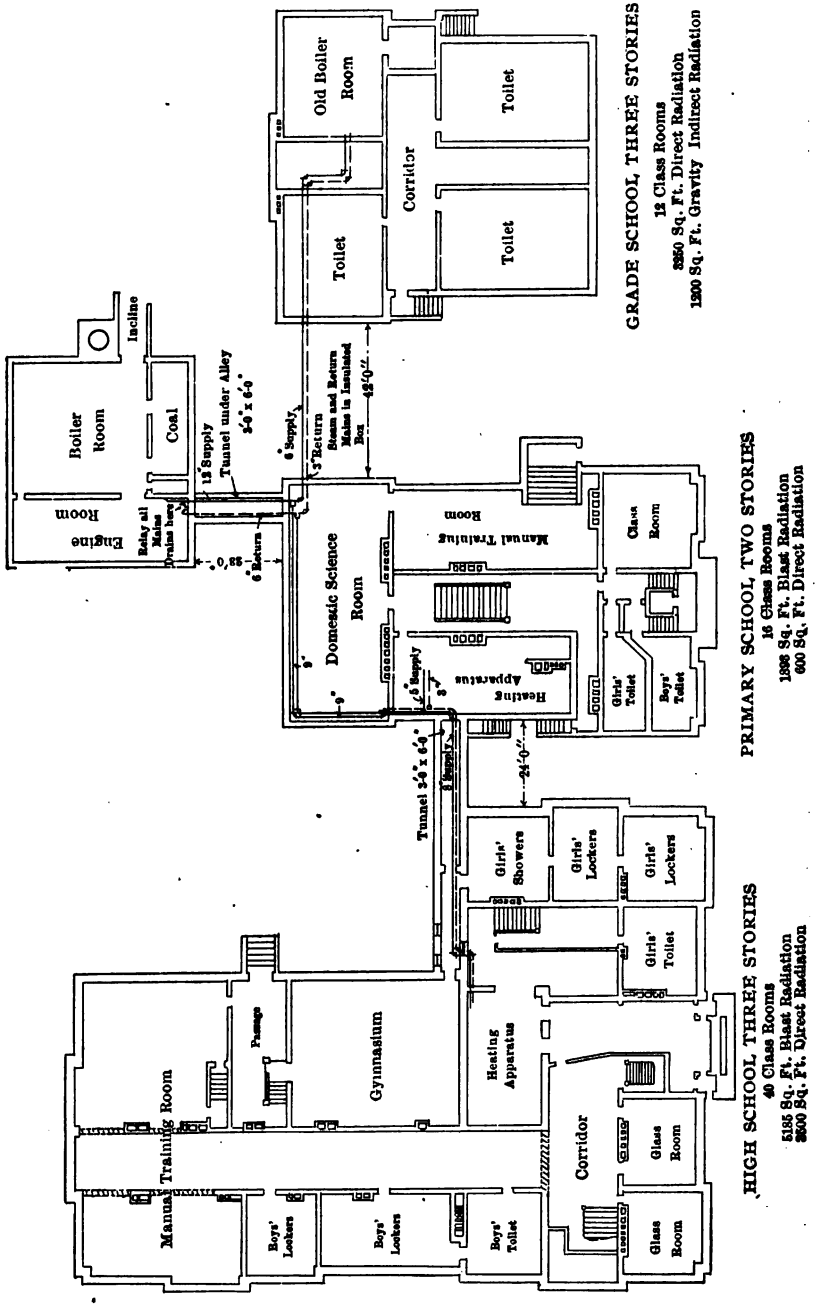


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tion, and it developed that the boilers in the Grade School, which is an old building, were worn out. Therefore the School District decided to furnish its own steam, power and lights. The basements of the buildings were required for other purposes, so a separate boiler house was decided upon.

The blast steam method of heating and ventilation was adopted for the High School, the type of plant being similar to that in the Primary School. The basement plans of both buildings are shown. The air is drawn through tempering coils to the fans, which discharge through heating coils and by-passes to plenum chambers. These chambers are each divided into two horizontal compartments; one containing tempered air at about 60 degrees Fahrenheit; the other containing heated air at about 130 degrees Fahrenheit. From these chambers single sheet metal ducts lead to vertical flues which supply the various rooms and departments. The single ducts each have double dampers in the connections to them from the plenum chambers, so that air at varying temperature but constant volume may be admitted. The flues discharge through adjustable diffusers at a distance above the floors of the rooms of about two-thirds of the height of the same. The ventilating grills are at the floor line on the same side of each room as the inlet openings. The ventilating flues are connected in the attic with sheet metal ducts, leading to ventilators in the roof. They also connect with vertical shafts leading back to the fans, so that the air in the buildings may be rotated. The temperature of the rooms and tempered air plenum chambers is automatically controlled. The dampers in the roof ventilators and return air shafts are controlled from the basement by compressed air. Direct radiation is installed in toilet rooms and corridors, and auxiliary direct radiation is placed in such other rooms as have plumbing apparatus, or which might be used by a small number of persons on holidays, or at night when the fans would not be in operation. Considerable study was required to install the apparatus in the space assigned, without having any great lack of symmetry in the air distribution, and it appears cramped on the plans, but there is ample room for attention and inspection, and there has been no trouble in warming the buildings, or in equalizing the air delivery.

Because of a large assembly room, seating over 500 persons,

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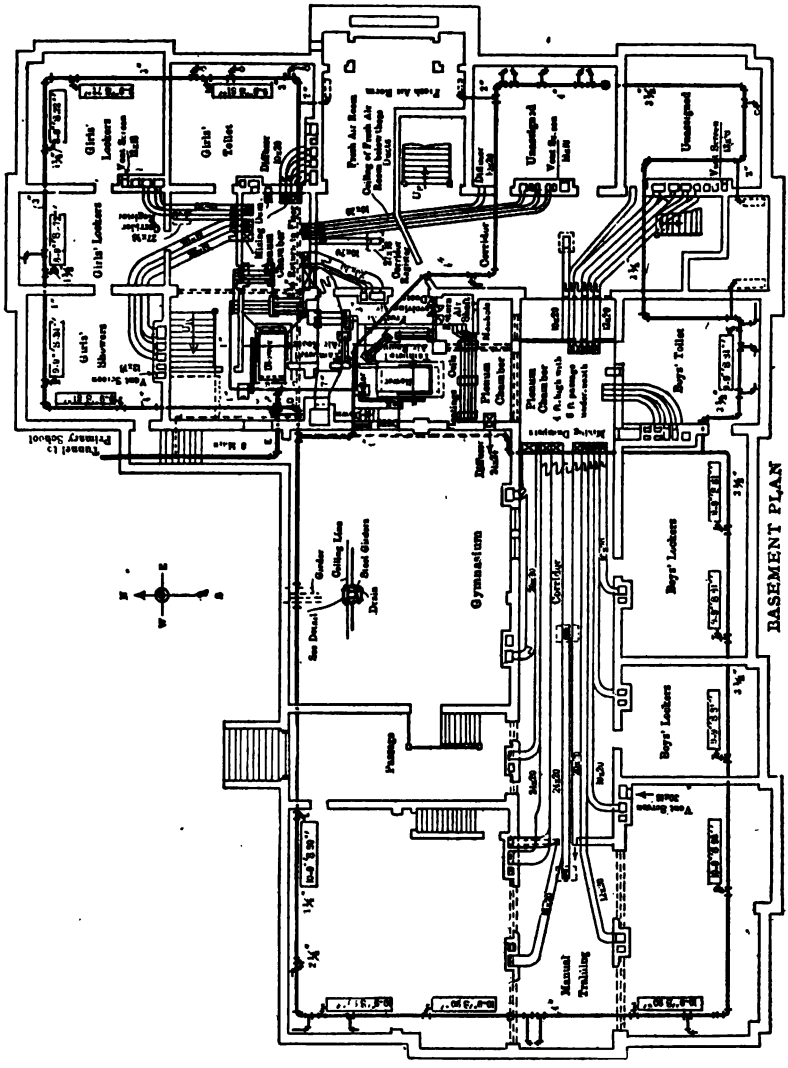
in the High School, often used for entertainments, one of the fans is arranged to serve that room alone when desired. The assembly air inlets are 16 feet above the floor, on the dead side




of the room, which has three sides exposed, and is 100 feet long. The ventilation is distributed and 320 square feet of auxiliary direct radiation is placed in the far end.

The fans are designed to furnish a minimum of 30 cubic feet of air per occupant per minute, at not to exceed ½ ounce press-

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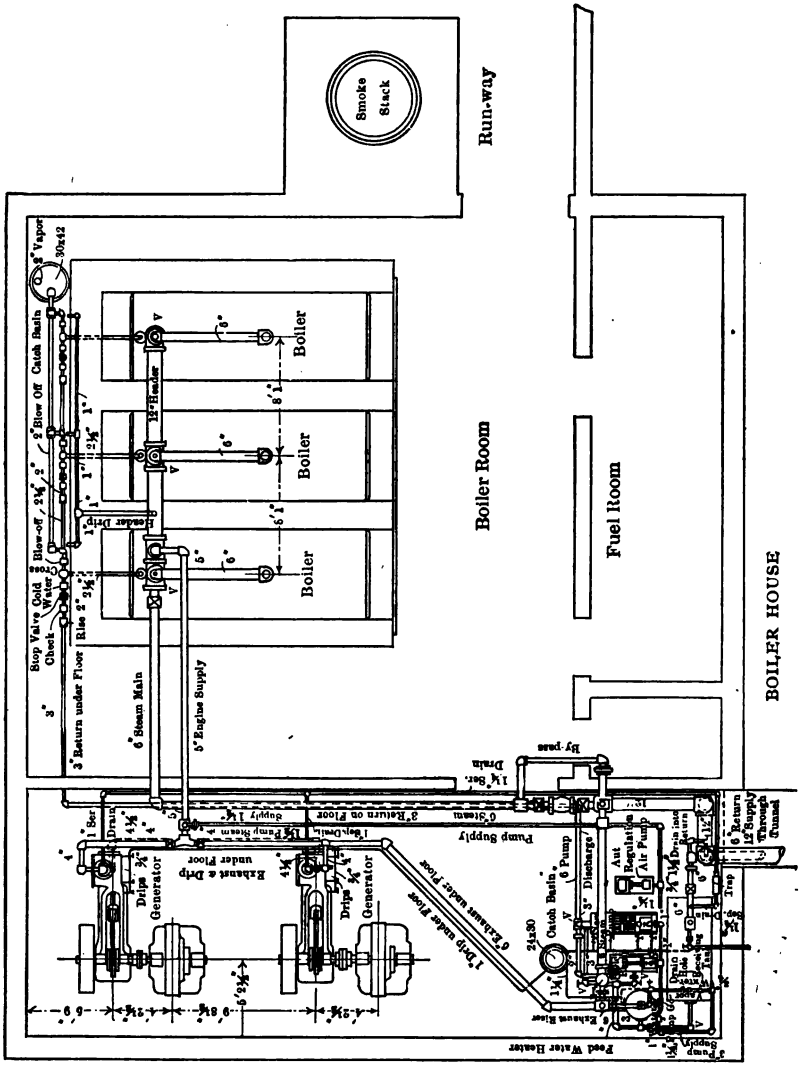
ure at the fans, at the same time furnishing sufficient air to change the volume in corridors, cloak rooms, etc., once every ten minutes. The ducts are calculated in general for a maxi-




mum velocity of not more than 800 linear feet per minute, and the flues for a maximum of not exceeding 600 linear feet per minute.

A velocity of 1,100 feet per minute is allowed through the blast coils. The Grade School, outline plans of which are shown,

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contains old style direct radiation on the two pipe system with gravity air supply warmed by cast iron indirect radiation. It will eventually be changed, in all probability, to a blast system similar to that in the other two buildings. The equipment of the three buildings is as follows:

| Building. | Cu. ft. contents. | Cu. ft. air per minute. | Sq. ft. blast radiation. | Sq. ft. direct radiation. | Sq. ft. indirect radiation. | Size blowers. | Size motors. |
|---|---|---|---|---|---|---|---|
| High School | 682,540 | 65,000 | 5,185 | 3,500 | ..... | { 1–8′ 6″ 1–8′ 0″ | 2–15H.P |
| Primary ... | 237,600 | 21,500 | 1,893 | 600 | ..... | 1–6′ 0″ | 1–7½H.P |
| Grade ..... | 276,558 | ..... | ..... | 3,250 | 1,200 | ..... | ..... |
| Totals.... | 1,196,698 | 86,500 | 7,078 | 7,350 | 1,200 | | |

In addition there is required about 15 horse-power for motors in the Manual Training Department, and about 900-16 C. P. lights.

The condensation in the blast coils was assumed at one pound of steam per square foot per hour, as they were 20 rows of pipe deep. Three-tenths of a pound of steam condensed per hour per square foot was allowed for the direct radiation. This has been found to carry sufficient capacity for mains of reasonable length. On this basis 330 boiler horse-power would be required, and boilers of 375 commercially rated horse-power were installed. The boilers have carried the load with ease. As shown on the plan, the boiler house is directly behind the Primary School, and is connected with it by a tunnel. The supply and return mains lead from the Primary to the High School basements through a tunnel, and to the Grade School through a double pine box, made water tight. The mains in the box are covered with asbestos one inch thick and packed in mineral wool. The tunnels serve as passageways, and also carry the electric wires. In the power house there are installed three 72-in.×16-ft. suspended horizontal tubular boilers with standard equipment. They are operated at 90 pounds pressure. Space is provided for the addition of a fourth boiler, which might be needed, should additions be made, or from which steam may be supplied to other buildings in the vicinity. There are two 12-in.×14-in. horizontal high speed automatic engines, two boiler feed pumps and a steam air compressor.

Steam is carried from the boilers through 6-inch outlets to

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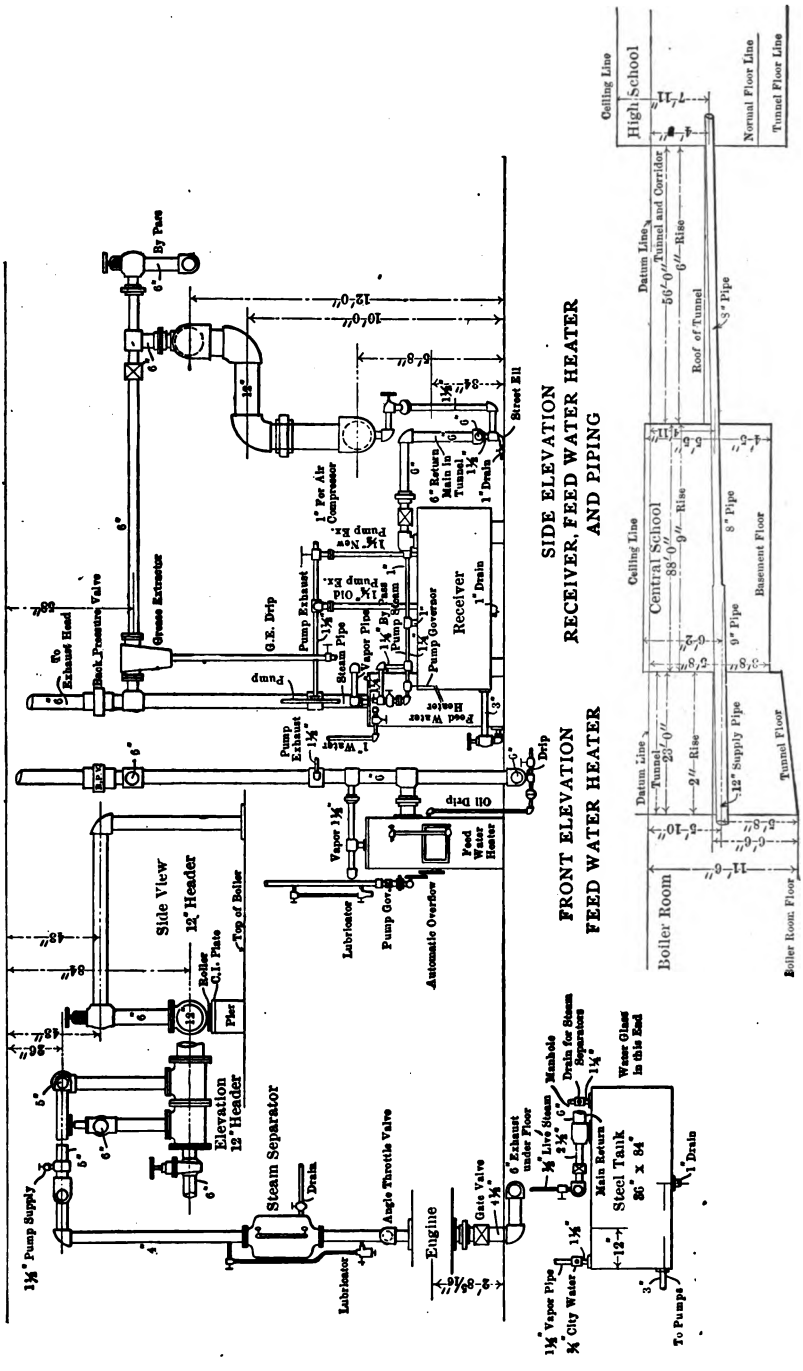


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a 12-inch header, which is self-draining through separate pipes with valves and checks below the water line of each boiler. The group of buildings is supplied with exhaust steam from the engines, and with auxiliary live steam as necessary through a 6-inch automatic pressure reducing valve. The low pressure steam supply is 12 inches, with an 8-inch branch to the High School, 5 inches to the Central School, and 6 inches to the Grade School.

The supply mains all pitch up from the boiler house, where they drain into the main return through a 1½-inch relay. While this causes rather slow heating up when steam is first turned on, there has been no trouble on account of expansion or water hammer, though this is the only drain in ordinary use. The expansion is all taken up with swing joints.

The main return is 6 inches, with a 5-inch branch from the High School, 3 inches from the Central School and 3 inches from the Grade School. The high pressure piping is all flanged. The engines are provided with steam separators and grease extractors, and exhaust through an open feed water heater into the heating system, or direct to the atmosphere through a back pressure valve. The feed water heater contains the pump governor, which operates either pump, and is in circuit with a large tank which receives the condensation from the heating system. Thus what little fresh water is needed during normal operation is heated and purified before entering the boilers. As only one boiler would ever be used for running one engine in weather when no heat is required, the feed water heater is of only 150 horse-power. One of the boiler feed pumps is 7-in.×4½-in. ×7-in., of the duplex type. The other is a single acting pump 6-in.×4-in.×8-in. Preference is given to the latter by the engineer, perhaps because it requires less attention. Duplicate pumps and engines were installed so as to reduce the danger of a shut down during school hours.

The engines are direct connected to two 50 kilowatt 120 volt direct current generators, running at 300 revolutions per minute. A three panel enamelled slate controlling and distributing switchboard is installed. The total load is about 80 kilowatts, but there is slight possibility of more than one-half of this capacity being required at any one time, so that the generators are practically in duplicate.

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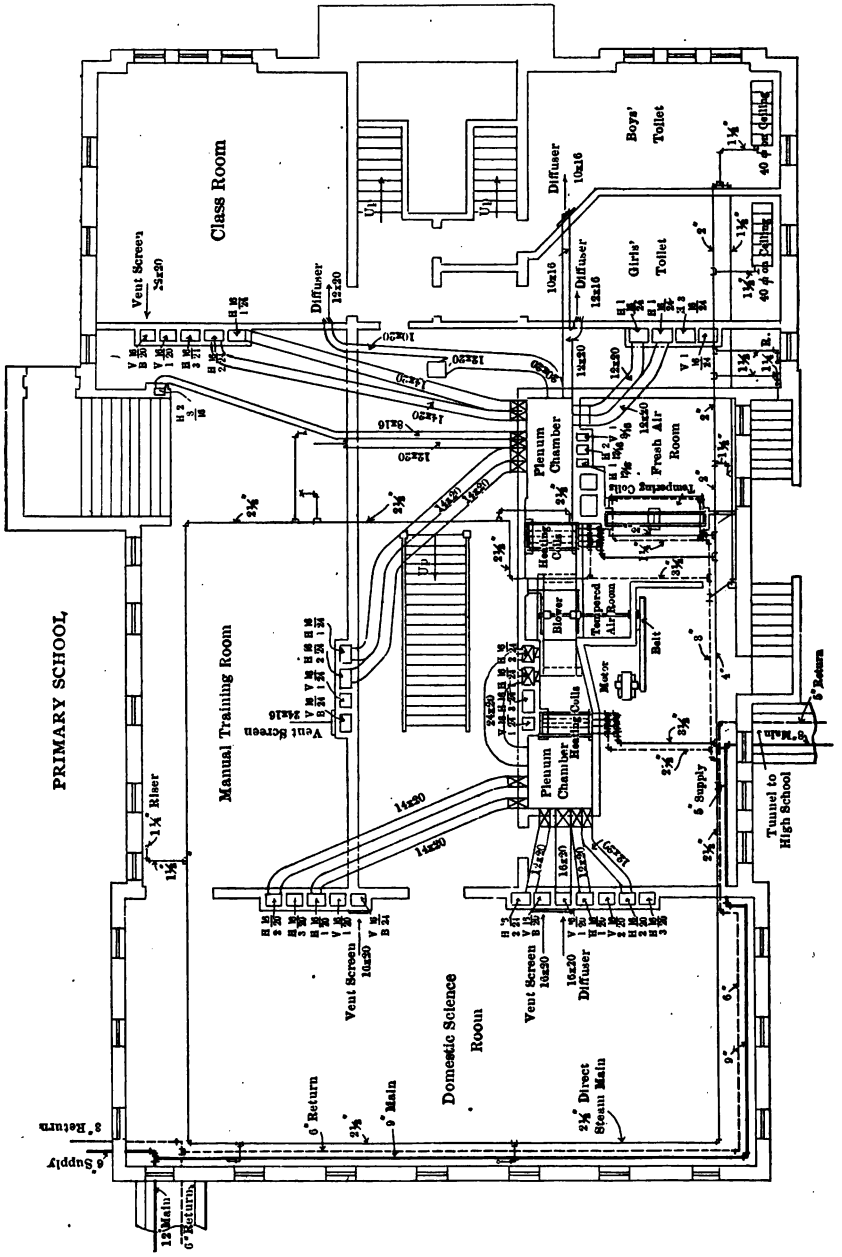


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The plant has been very satisfactory in operation. The fuel cost for heating, ventilating and lighting the buildings has been $2,066 for the season of 1906-1907. This is at the rate of $1.727 per thousand cubic feet in the buildings per season. There is no connection for power from outside sources, and the above cost includes the lighting and ventilating on many days and evenings when no heat was required, thus involving a higher operating cost than a mere heating equipment would show. An engineer and one fireman have operated the plant. The expense for attendance has been no greater than it would have been had the janitors of each building handled ordinary systems located therein. The expense to the school district has been at least $1,000 per year less than it would have been had the electricity and steam been purchased. The gain in space in the buildings; absence of fire in them; elimination of boilers under school rooms; ability to burn cheap fuel economically; absence of dirt and dust—all point to the advantage of a separate power plant under the conditions stated. The mechanical equipment of the High and Primary Schools and boiler house cost approximately $30,000.

## DISCUSSION.

Mr. Lewis: The particular interest in this plant is that, unlike the ordinary central heating plant, it takes care of buildings that are only heated during school hours. I think there are only four or five plants of that kind in the country. Most central plants for a group of schools take care of dormitories and cottages, which are heated continuously.

Referring to the tabulation on page 192, the amount of heat required, the amount of coils, etc., all depend on the number of pupils; we contemplate furnishing thirty cubic feet of air per pupil per minute; to heat that amount of air requires more power than needed merely to heat the building; so we did not need to take into consideration the loss of heat through the walls, windows, or anything of that kind.

There is one line of discussion I would like to suggest: In the competition through this territory there is constant warfare between those who advocate one or the other of the two types of school heating systems. One is a central blast heating plant,

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with separate ducts leading to each room, with a damper in each separate duct, so that the heat and ventilation is controlled from the basement. There is no direct radiation except, possibly, a little auxiliary to aid in warming up the chairs and desks, because until they get warm the room is not habitable. The other type of plant is one in which the air is drawn along through the coils and heated to 70 degrees. The air is blown into all rooms of the building at the same temperature. The temperature in each room is controlled by turning on or off by hand or automatic regulation the direct radiators, of which enough is ordinarily put in to heat the room independent of the air. Each type of plant has its adherents. I like the central plenum chamber, with separate pipe to each room, best.

Prof. Allen: Mr. Lewis speaks of different systems. I think each system has its place. At the University of Michigan we have adopted a uniform system of heating the buildings. We use direct heat for keeping buildings warm and fans for ventilation. The ventilating system and heating system are entirely separate, both, however, are controlled by automatic control. The object in doing this is to save fuel. As soon as the students enter the building in the morning, say at 8 o'clock, the fans are turned on and at 4 o'clock, or when the students begin to leave the building, the fans are turned off. The ventilation is then only kept in operation during the time the building is occupied. The direct radiation, however, is kept on at all times, so that the building is never allowed to cool. This enables us to operate at minimum expense. Referring to the double duct system of hot air pipes in the fan system, this is the most desirable system where it is necessary to heat and ventilate rooms in the same building and where these rooms are kept at different temperatures. As, for example, a Y. M. C. A. building: The gymnasium is usually heated to 65 degrees, and the dressing-rooms and other rooms to 70 degrees. This difference of temperature can be controlled with the double duct system.

Mr. G. D. Hoffman: I should like to inquire of Mr. Lewis, when he speaks of the swing joint, if he means a 90-degree turn where the two pipe lines are on the same plane, or if he lifts one by means of two elbows and a coupling, what is the minimum length of straight expansion that would be allowable, say in a 100-foot run?

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Mr. Lewis: There are no rigid joints. It is a swing in all instances, with two elbows.

Vice-President Mackay: What is the length of the expansion?

Mr. Lewis: Four or five inches.

Vice-President Mackay: One swing joint in every 100 feet or less.

Mr. Lewis: There are several rightangle turns. At one end of each of those long, straight runs of pipe there is an expansion joint of that kind.

Mr. G. D. Hoffman: I would like to inquire further, if there is at any time any difficulty in keeping those joints tight, even at a pressure of ten or fifteen pounds?

Mr. Lewis: There has not been any difficulty in that.

Mr. L. A. Larsen: I would like to ask Mr. Lewis a question. He says he did not have to apply the rule regarding the exposure or the amount of air. You figured it altogether on the number of pupils you furnish air for. In getting at that, do you not have to apply some rule first?

Mr. Lewis: In the ordinary schoolroom, where there are thirty or forty pupils, from previous knowledge in having figured it out, I knew it required an air change at this temperature once about every fifteen minutes. In the average of these rooms we are changing the air every seven or eight minutes. In a few rooms the air is proportioned by Rule A, given this morning.

Mr. Larsen: What amount of radiation on a blast coil do you need in comparison with direct radiation? What rule would you use to get at that?

Mr. Lewis: A simple thumb rule is this: Having the number of pupils and thus knowing the cubic feet of air per minute, divide the cubic feet of air required per minute by four. That gives the number of linear feet of pipe required in the blast coil.

Mr. Larsen: There was another question raised by a member from Michigan that appears to be adverse to my experience at Duluth. He says he can heat his building cheaper with direct radiation than he can with blast coils. Last year we built two new buildings and we put in practically the same plant that is laid out here by Mr. Lewis, with a few exceptions in minor details. One of those buildings was ready to turn steam into the direct radiation—by the way, we had both direct radiation and the blast. I did that because the School Board in Duluth

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would not permit putting in a direct or simply a blast system. They were afraid of it, but I had investigated far enough to believe that a blast system was all right. So I put in plenty of coils to run this building with blast alone without the directs, but still put in the directs. This plant was ready to turn steam on into the directs the 1st of December. The fan system was not ready until the 10th of January. We heated the building for the contractors to finish their work during December, and the first ten days in January, with direct radiation. When I had the fan system ready I turned that on and I heated the building the rest of the winter for the contractors to finish up, with about a third less fuel than I could do by using the directs alone. I used nothing but the fans the rest of the winter. That is my experience with the blast up there, and the reason I asked this question of Mr. Lewis about the radiation is that the rule I use is the rule that is laid down by the Scranton School. In that rule it is required that we proportion the amount of heating surface by first figuring the exposure and reducing that to the equivalent of glass, and then figure the amount of air changes we want and the air escape will be, of course, the same amount that we pump in. Multiply the amount of air delivered into the building by nine-tenths—there is nine-tenths of a B. T. U. of heat delivered by a cubic foot of air in cooling from 120 degrees down to 70 degrees—it gives you the amount of heat that is given off by the air changes; and add that to the amount of heat lost, figured from the glass exposure, gives you the amount of linear feet of pipe. That is the rule I use. I want to know how near that is right. That is the reason I ask the question.

Mr. Lewis: I think that checks up very closely; but the prime requisite of a ventilating plant is to provide a given amount of air for each pupil in the room. There are other arguments in favor of direct radiation and against it. My own belief with reference to direct radiators in schoolrooms is that their business is to pump as fast as they can the foul air and dust and dirt into the room, the circulation being from the floor up through the radiator to the ceiling. The business of the ventilating plant is to force the foul air to the floor and out through the vent opening. Thus the two systems are working in opposition to each other. I believe if we could have direct radiators in the rooms, to warm them quickly in the morning only, and the blast

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in addition, to be used during occupancy, it would be better—practically putting in two heating plants. I believe Mr. Waters, of the Chicago Board of Education, has a tabulation of the fuel cost in the Chicago schools, and while all blast plants have many modern means of economy over some of the early ones, which have both blast and direct radiation, the economy of fuel is very much greater in the all-blast plant than in the others.

Prof. Allen: Possibly you misunderstood the condition. The use of a system which combines direct heat in the room with fan system for ventilation would not ordinarily be applied to a ward school. I had in mind the conditions which exist at the University. In a number of buildings our fans are nearly one-half the size necessary to supply air. The classrooms are only used in the morning, the drawing-rooms and laboratories in the afternoon. The building is provided with automatic dampers, by which air can be cut off classrooms in the afternoon, and the janitor only puts air into such rooms as are being used. This gives us a different condition than we would expect in ordinary ward buildings.

Mr. Larson: May I ask Mr. Lewis another question? Supposing he has a room of 12,000 cubic feet, and it takes, we will say, 240 square feet of direct radiation to warm that room, how much blast coil would you need for that room? Would you need more or less than for direct radiation?

Mr. Lewis: You would need considerably less if it were a direct coil. For instance, in an eight-room building it might require 2,500 square feet of direct radiation and that building would only take 1,200 feet of blast radiation to get the same result. It is three times as efficient per square foot.

Mr. Larson: That bears out my doctrine. I have gotten into an argument with a heating man and I have about the same percentage in my blast coils as Mr. Lewis names. I have got 1,400 and some feet of coil. He has been trying to convince the board that I have not got enough radiation. I want to satisfy myself whether I am right or wrong.

Vice-President Mackay: Roughly speaking, a blast coil containing two-thirds less surface than the necessary amount of direct radiation will do the work of the direct radiators. I think that is the way Mr. Lewis states it. Is there any further discussion on this paper?

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Mr. Lewis: One point was brought up this morning by Mr. Swan regarding the facility with which you could heat fresh air or foul air. A neighbor of mine, sitting beside me, mentioned the fact that he had found in his experience in heating school buildings, that with the fan system he could heat a building much quicker in the morning by taking the cold air from outside than by drawing it from the building. I do not think it had so much to do with the quality of the air as that when rotating, on account of the greater friction and resistance in the air passages, he was not throwing as much air. I do not think it makes any material difference whether it is fresh air or foul air. I have never seen a rotating system, wherein you suck the air back from the roof, with which you could heat up as quickly in the morning.

Mr. Donnelly: In reference to Mr. Lewis's point about a direct radiator in a room in connection with the hot blast, I will say I was out in Massachusetts ten or twelve years ago, where they made it the invariable practice to insist upon the direct radiator being put directly under the fresh air inlet, on the warm side of the room, so the current of air from the radiator would mingle with the other and cause less conflicting currents, and by smoke tests of that style they found it interfered very much less than by putting coils around the rooms or by putting radiators on the cold walls.

Mr. Lewis: Do not lose sight of the fact that direct radiation often, even in a room heated by blast, is a life-saver, because sometimes we get an unusual area of skylight or window and the pupils back there get cold draughts.

Prof. Allen: Mr. Lewis brings up a point that is very important—that of high windows and a large amount of glass surface. When a fan system alone is used there is a down draught near the large window surface. By putting direct radiation directly beneath this glass surface this down draught is materially reduced and the effect of heating greatly improved.

Vice-President Mackay: There can be no doubt about that. That is the function of the direct radiator. I think that Mr. Lewis, in giving the condensation of direct radiation per hour, was very conservative. If he was only condensing the quantity he states, the radiation was not as effective as it should be or

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he was using more radiation than necessary. A direct radiator should condense more than he states.

Mr. Lewis: I have never made any tests, but from what I could gather from technical books it always seemed to me that three-tenths of a pound of steam condensed per square foot per hour was more than any radiator would do, and that this three-tenths allowance in figuring boiler capacity was probably enough to provide for the steam and return piping also.

Prof. Allen: We have conducted a series of experiments at the University of Michigan, covering some 400 or 500 tests on various forms of radiation. The condensation of steam per square foot of radiation for a two-column, cast-iron radiator does not exceed one-quarter of a pound. The average number of these tests show this condensation to be about 0.24 of a pound.

Vice-President Mackay: In checking that up you use commercial rating?

Professor Allen: Commercial rating.

Mr. Larson: Suppose we have a building where it is impossible, for the lack of room, to put in a coil. Can we get the same results by placing indirects in the basement and ducts in each room, providing we use the same amount of radiation and have our mixing dampers between the indirect and the room?

Mr. Lewis: I think you are getting practically the same results when you are operating the fan and heating the building at the same time, but with this partial direct plant you lose one advantage of the all-blast system. In the ordinary direct system you have your radiation scattered out through the building. The sun shines from the south and affects the warming of that side of the building very much. The north wind is blowing on the other side and the rooms are cold. On this particular morning, if you could take half of the direct radiation lying idle on the south side to help out on the north side you would get along better and save fuel. With the blast system, when the rooms on the south side get warm, the heat is shut off and is available on the other side.

Secretary Mackay: I would like to say that our practice in the East, in school buildings, library buildings and hospital buildings of large size, is largely to place cast-iron, indirect radiation at the base of the flue instead of in a plenum chamber, and that we seem to get better results from it and we do not use the fan

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at all times. There was one point Mr. Larson made—I do not know whether he used the fans for twenty-four hours a day in heating the building, for temporary heat, or used it only when the workmen were in the building, and whether direct radiation was used at the same time. He makes inquiry as to whether there is greater economy in fuel between the blast system and direct radiation. I want to ask him if he used both systems the same length of time, or if he used the direct twenty-four hours a day and the hot blast only when the workmen were in the building.

Mr. Larson: In this case we used it twenty-four hours, because we were drying out the building; but we used it in the other buildings at 70 from 8:30 o'clock and we shut our fans down the minute the scholars left the building.

Secretary Mackay: Was your direct enough to heat the building without the indirect, or did you have more radiation, in proportion, in your direct than you had in your indirect?

Mr. Larson: I had plenty of radiation in the blast coils to heat the building as I figured, but the directs were not enough to heat it under all conditions. It was simply to help out. The rooms contained about 10,000 cubic feet each, and there was 180 feet of direct radiation in each room.

Secretary Mackay: So that the hot blast was really under more favorable conditions for heat than the direct.

Mr. Larson: Yes; in our country we have very severe weather, and that is the reason they were not satisfied to run chances of putting in a blast job unless it had been tested; so, as I said before, I put in what ought to be enough, a coil of twenty-eight rows of pipe—6-ft. pipe, 7-ft. base—and if that would not be enough we would not dare try it. Now we are satisfied it will work and we are designing two plants of the blast type. One of them is the renewal of an old plant where I did not have room to put a coil in the basement, and therefore I put in the indirects under the flue. The other is a new building, and I am going to put them all in two banks—eight rows of pipe in the tempering coil and twenty rows of pipe in the main heater coil.

Mr. Lewis: I think I can explain the reason that happened. Our conception of direct radiation is based on the idea of having it in a tight room. Only for the first few minutes the direct radiator is in operation does it get cold air. After that it is in

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contact with comparatively warm air, as the room gets nearer and nearer the temperature of the radiator, and the amount of steam condensed becomes less and less. In a number of instances we have had boilers connected up to radiation throughout new buildings while they were under construction. "Oh, that boiler is not big enough," they cried, but when they got the windows in and the building was tightened up it was different; and that is the reason there was trouble and expense heating that building with direct radiation.

Mr. Larson: The windows were all in and the building was closed, as far as the outside walls were concerned. The partitions were not finished, but the roof was on and all the windows in, in perfect shape.

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## CLXXX.

# THE DESIGN OF A PLENUM SYSTEM OF WARM AIR HEATING FOR A SCHOOL OR OFFICE BUILDING.

BY J. D. HOFFMAN.

(Member of the Society.)

1. *Object of the Paper.*—In the following discussion, the three building plans, Figs. 1, 2 and 3 may, for our purpose, represent a typical two-story and basement office and school building. The object of the writer has been to work through the important parts of the design to show how such a line of work could be accomplished.

The subject of heat loss from the building is one in which a comparison of the results obtained from the various formulas would have been valuable; but since such comparisons have frequently been made, it was thought best to confine these remarks mainly to the calculations around the heater room and in a brief way to the lay-out of the ducts and registers.

2. *Heat Loss from the Building.*—The formula

$$\text{Radiation loss} = \left(G + \frac{W}{4} + \frac{nC}{55}\right)(T - t)$$

was used in calculating the heat loss from the building. In this formula $n$ is given with the other values in Tables I, II, and III; also $T - t = 70$.

It will be seen from Tables I, II, and III that the total heat loss from the walls and windows is 1,483,251 B.T.U. per hour; with an outside temperature of 0° F. and an inside temperature of 70° F. Now if the air leaves the heating coils at 140° F., which may be considered the best service for a cold day, then the heat radiated from the walls and windows will equal the heat wasted in the exhausting of the air from the building and the total heat lost from the building will be

$H = 1{,}483{,}251 + 1{,}156{,}935 \times (70 - 0) \div 55 = 2{,}966{,}502$ B.T.U.

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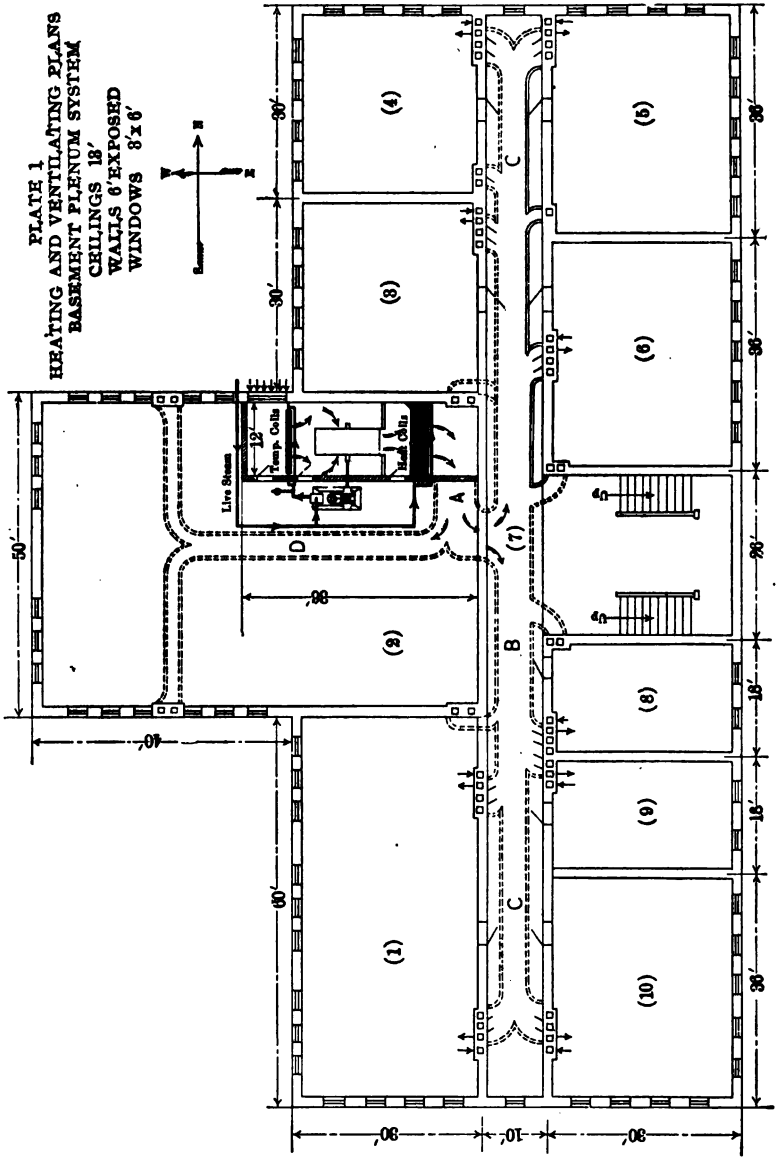
3. *Amount of Air Needed as a Heat Carrier.*—In column 6 of the tables are tabulated the volumes of air needed to carry




the heat to the various rooms. These values are obtained by multiplying the heat loss by 55 and dividing by 70; = heat loss × .78.

4. *Coil Heating Surface, Method No.* 1 *Figured from Heat*

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*Loss Principally.*—Assume a velocity of the air at the coils of say 750 feet per minute, then (Carpenter, H. & V. Par. 54) the number of heat units transmitted per square foot per degree difference in temperature bewteen the steam within the coils and the air surrounding the coils is 7. With the steam in the coils at 227° F. (5 pounds gauge) and the average temperature of the air around the coils at $(140 + 0) \div 2 = 70°$ F. the square feet of H.S. in coils $= \frac{2,966,502}{7\ (227 - 70)} = 2,700$. This is equal to $(2,700 \times 3)$ 8,100 lineal feet of 1-inch pipe.

*Check* 1.—In such a design as this the coils would be banked up from 16 to 20 rows deep in the heater. Under such conditions the heat transmitted per square foot per hour per degree difference between the temperature of the steam and the entering air is 4.7 B.T.U. (Car. Par. 52) and we have square feet of H.S. $= \frac{2,966,502}{4.7\ (227 - 0)} = 2,900 = 8,700$ linear feet.

*Check* 2.—The total volume of the building is approximately 500,000 cubic feet. If 75 cubic feet of space be allowed for each lineal foot of 1-inch pipe in the coils (Sturtevant, Ventilation and Heating, Page 33) we have $500,000 \div 75 = 6,666$ linear feet of pipe in the heater.

5. *Coil Heating Surface, Method No. 2 Figured from Air Supplied for Ventilation.*—In the above calculation for the heating surface the heat loss from the building was the principal consideration. This gave approximately 2.5 changes of air throughout the building per hour. In most cases a building heated in this way will give satisfaction, because the extreme temperatures assumed would seldom be needed and the air velocity could easily be increased to 1,000 or 1,200 feet per minute, thus giving opportunity to provide more air for the ventilation at a permissible reduction in temperature as it leaves the coils.

If, however, the ventilation of the building is an important factor, the safest method would be as follows:

Assume say 4 changes of air per hour in the entire building, which is this case is 2,000,000 cubic feet. This may be figured by individual rooms if desired. If this air is all heated from 0° F. it will carry from the building (at 70° F.) $2,000,000 \times 70 \div 55 = 2,545,454$ B.T.U. per hour. The total heat loss from the

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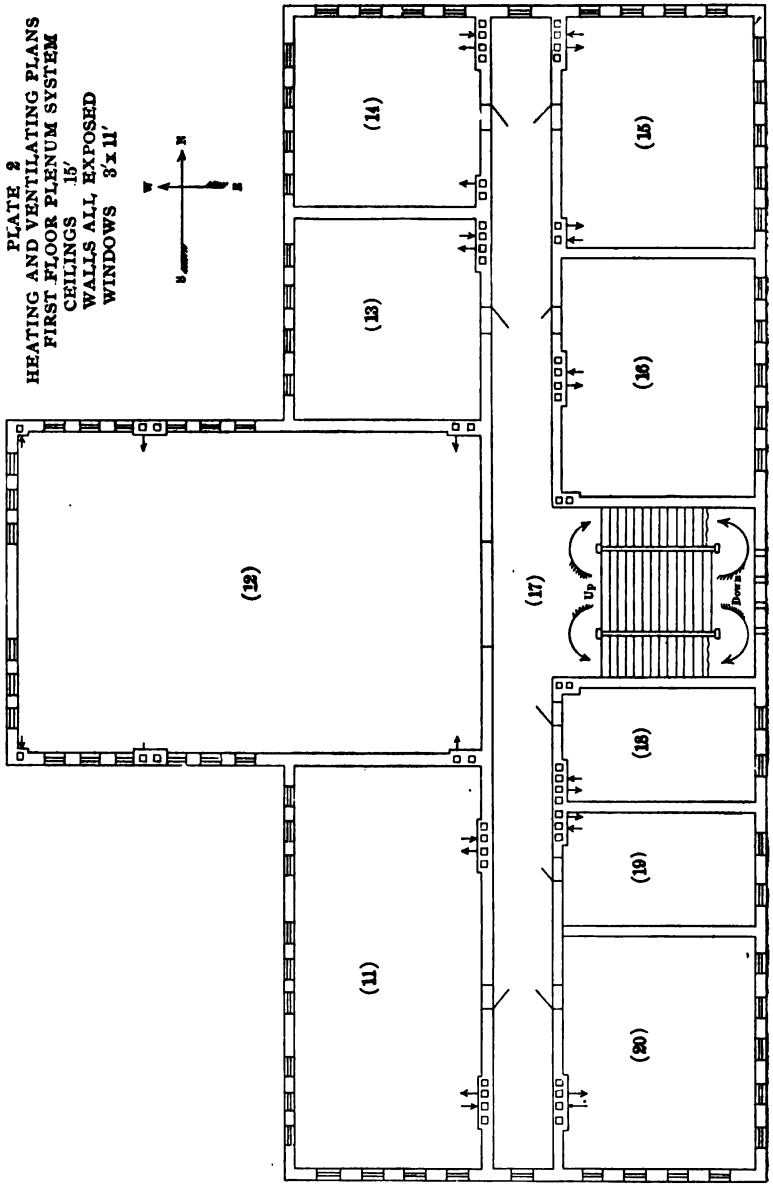
building would then be 2,545,454 + 1,483,251 = 4,028,705 B.T.U.




The *temperature* of the air *leaving* the *coils* is therefore 4,028,705 × 55 ÷ 2,000,000 = 110° F. With a required temperature of 110° F. for the air and a steam pressure of 5 pounds

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gauge we will need 4 sections of coils of 4 rows each, or 16 rows in depth in the heater. Under such conditions the efficiency of the heating surface is approximately $2\sqrt{V}(T - t) = 2\sqrt{12.5}(227 - 0) = 1{,}544$, say, 1,500 B.T.U. per square foot per hour. Where $V$ = velocity of air in feet per second, $T$ = temperature of steam and $t$ = temperature of the entering air.

From this is found the square feet of H.S. $= \frac{4{,}028{,}705}{1{,}500} = 2{,}686$.

Then $2{,}686 \times 3 = 8{,}058$ lineal feet of coils.

*Check* 3.—One quotation gives 200 lineal feet of pipe for each 1,000 cubic feet of air per minute, at a velocity of 1,500 feet per minute at the fan and temperatures from 0° F. to 120° F. This gives $2{,}000{,}000 \times 200 \div 60{,}000 = 6{,}666$ lineal feet.

6. *Changes of Air Needed in the Building.*—Assume a maximum of 1,200 students to use the building at any one time and that each one will need 30 cubic feet of fresh air per minute. This will require $1{,}200 \times 30 \times 60 = 2{,}160{,}000$ cubic feet of air per hour. $2{,}160{,}000 \div 500{,}000 = 4.3$ changes of air per hour, which agrees fairly well with the assumed number of changes in Sec. 5.

7. *Arrangement of Coil Surface.*—Having given from the calculations 8,100 lineal feet of coils, this may be divided, as a trial effort, into four sections of four rows to the section, with one section used as a tempering coil and three sections as heating coils. This gives 2,025 and 6,075 lineal feet respectively in the heaters. If there are 16 rows of pipes, each row will contain 506 lineal feet, or 168 square feet of surface. With an air velocity of 750 feet per minute at the coils and a total of 1,156,935 cubic feet of air passing per hour, the *free area* of cross section will be $1{,}156{,}935 \div (750 \times 60) = 25.7$ square feet. The *gross area*, therefore, is approximately $25.7 \div .45 = 57$ square feet. This will require a single section heater of $7 \times 9$ feet, or a double section heater (sections set end to end) of $5 \times 6.5$ feet. Upon inspection of the heater sizes we find that the free area is satisfactory, but that there is not sufficient heating surface, since each row of coils of a $7 \times 9$ heater contains only about 116 square feet of surface.

It will be necessary, therefore, to install twenty rows (five double sections of four rows to each section) and place say one double section as a tempering coil and four double sections as

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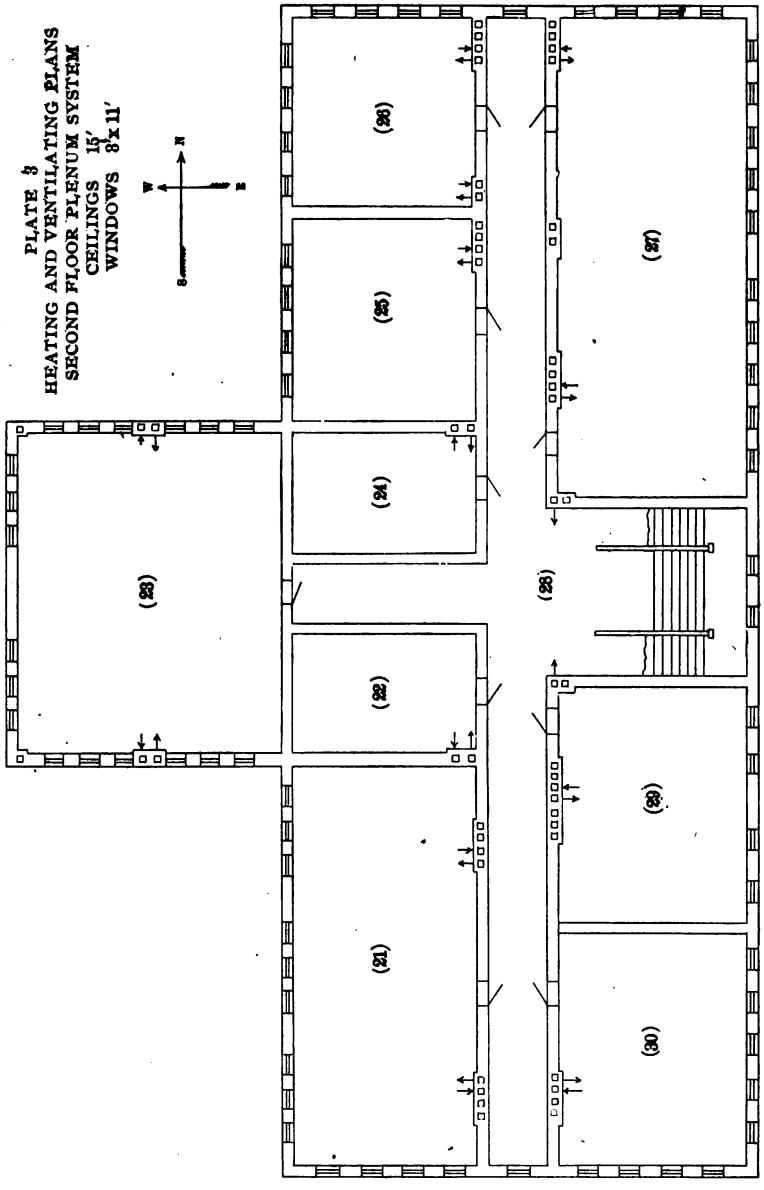
heater coils. With this arrangement the size of each section of a double section heater may be 5 × 7 feet, making 70 square




feet total gross area and approximately 28 square feet of total free area. It also provides 67 square feet of coil surface per

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single section row, making 134 square feet of surface in each of the twenty rows. (Required 135 square feet.)

8. *Size of Fan.*—Select a steel housed paddle wheel fan direct connected to a low-pressure engine. Assume 250 revolutions per minute as a maximum and the pressure of the air to be 1 ounce; then (Car. Par. 162) the diameter of the fan wheel is

$$D = \sqrt[3]{\frac{\text{cu. ft. of air per min.} \times 10}{4 \times 250}} = 5.8, \text{ say 6 feet.}$$

From Sturtevant's Mechanical Draft, Table 112, we find that a 6-foot fan running at 250 revolutions per minute can maintain a pressure of about .88 ounce. This might probably be safer, considering a possible increase in the air required for ventilation, if a 6.5 foot fan were installed to run at say 200 revolutions per minute. The pressure maintained, however, would probably drop to less than .6 ounce, unless the speed were kept up to 250 revolutions per minute, in which case the pressure would reach 1 ounce.

*Check.*—Let the velocity of the air at the outlet of the fan casement be 1,800 feet per minute and assume that the efficiency of the fan delivery is 50 per cent., then the peripheral velocity of the fan blades is 3,600 feet per minute and at 200 revolutions per minute will give a 5.8 foot fan wheel. This shows that the above sizes are ample.

The *fan outlet* at 1,800 feet per minute air velocity is 1,156,935 ÷ (60 × 1,800) = 10.7, say 12 square feet. A good rule used by some is to make the area of discharge $A = 2 \times$ diameter in feet, which in this case would be 12 square feet.

The *double fan inlet* will be (considering the area of inlet = area of outlet) about 3 feet diameter.

9. *Horse Power of Fan.*—At 250 revolutions per minute, a 6-foot fan with a pressure of 1 ounce will require (Car. Par. 162)

$$\text{H.P.} = \frac{D^5(R.P.S.)^3 \times 20}{1{,}000{,}000} = 10.9, \text{ say 12.}$$

10. *Size of Engine Required.*—Assume that the steam is taken from a central power plant and delivered to the building through conduits at a pressure of 30 pounds gauge (45 pounds absolute); that the steam is exhausted into the coils at a pressure of 5 pounds gauge (20 pounds absolute) and that the engine cuts off at 25 per cent. of the full stroke; then the mean effective pressure in the cylinder is

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$$P = p\left(\frac{1 + \text{hyp. log } r}{r}\right) - \text{back pressure},$$

$$P = 45\left(\frac{1 + 1.386}{4}\right) - 20 = 6.8 \text{ pounds.}$$

The sizes of the cylinders are obtained from

$$H.P. = \frac{2\,PLAN}{33{,}000}$$

$$LA = \frac{12 \times 33{,}000}{2 \times 6.8 \times 250} = 117.$$

If $L = 12$ inches, then $A = 117$ square inches and $D = 12.2$, say 12 inches.

11. *Amount of Steam Used per Hour in the Coils.*—The amount of heat given off from one pound of good dry steam in

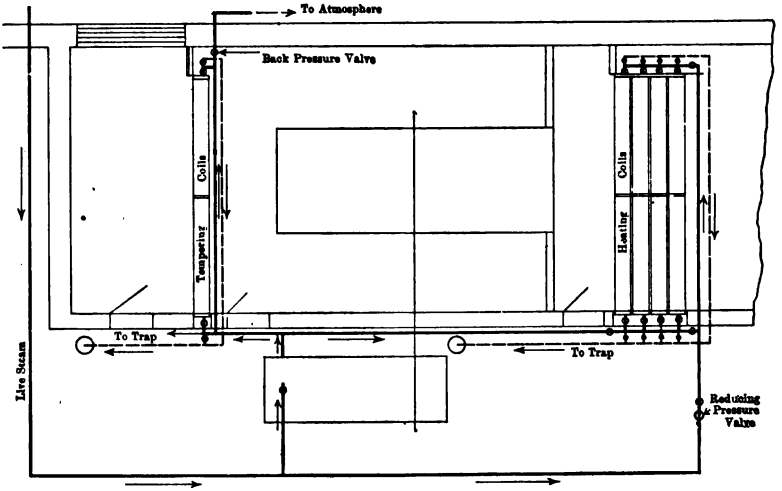


PLATE 4 PLAN OF PIPING CONNECTIONS

condensing from 5 pounds gauge to water at atmospheric pressure is 1,183 − 212 = 971 B.T.U. The amount of steam, therefore, needed per hour to supply the building with heat on a zero day is 2,966,502 ÷ 971 = 3055 pounds, where only enough air is used to serve as a heat carrier; and 4,028,705 ÷ 971 = 4,150, where at least four changes of air per hour are required for ventilation. This means 1.1 pounds of steam per square foot of heating surface per hour in the first case and 1.5 pounds per square foot of heating surface per hour in the second case.

12. *Boiler Horse Power Needed.*—If the engine uses 35

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pounds of steam per horse power hour, or a total of 420 pounds per hour, and the heating value of the exhaust steam is only 75 per cent. of that of dry steam at the same pressure, then the exhaust steam will supply to the coils an equivalent of $.75 \times 420 = 315$ pounds of steam per hour, leaving $4{,}150 - 315 = 3{,}835$ pounds of steam to be supplied direct from the boiler. The total dry steam therefore needed from the boiler for the plant will be $3{,}835 + 420 = 4{,}255$ pounds per hour, or approximately $(4{,}255 \div 34.5) = 123$, say 125 boiler horse-power.

13. *Size of Ducts.*—Assuming 2,000,000 cubic feet of air to pass through the main heat duct *A* per hour at a velocity of 1,800 feet per minute, the duct will be approximately 20 square feet in cross section, say $2\frac{1}{2} \times 8$ feet. The two main branches *B* will carry about 800,000 cubic feet per hour each at the same velocity and will be 7 + square feet in area, or $2 \times 4$ feet. The same branches at *C* will carry about 400,000 cubic feet per hour each at a velocity of say 1,500 feet per minute and will be 4.4 square feet in area, or say $2 \times 2\frac{1}{2}$ feet, and the west branch *D* will carry about 300,000 cubic feet at a velocity of 1,200 feet per minute and will be say $1\frac{1}{2} \times 2\frac{3}{4}$ feet.

The calculated duct sizes, of course, refer to the heat duct. The cold air duct need not be so large, because on warm days, when only tempered air is needed, the steam may be turned off from one or more of the heaters and the heat duct can then be used to furnish what otherwise would be required from the cold air line. On account of this flexibility it seems only necessary to make the cold air duct from one-half to two-thirds the cross sectional area of the heat duct. For convenience of installation, therefore, the former will be made of equal width to the latter and say one-half as deep.

Concerning the construction of the ducts, it is here (Plate I) represented as brickwork with some satisfactory division between the cold air and the hot air lines, and with a covering that will be suitable to the floors to be installed in the building. The former may be merely sheets of galvanized iron and the latter may be galvanized iron where a timber floor is used, or it may be *T* irons covered with brickwork and cemented if a concrete floor is used.

14. *By-pass Arrangements.*—In the plans as shown it is as-

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sumed that the coils will be set high enough to allow by-pass dampers to be installed beneath them. These dampers must be controlled from the engine room side and should have say two-thirds of the free area at the coils.

15. *Register Sizes.*—The net register was figured from an air velocity of 300 feet per minute and the sizes of the registers (catalogue sizes) were estimated to be 1.6 times the net area.

16. *Stack Sizes.*—The stacks were first figured for a velocity of 600 feet per minute and then sizes were assigned to fit the laying of the brickwork such that the velocities varied anywhere from 300 to 600 feet per minute.

All stacks should be plastered to a smooth surface on the inside and should have the tops corbeled to a curve so as to avoid a square or dead end.

TABLE I.

BASEMENT FLOOR DATA SHEET.

| Room. | n | Heat loss in B.T.U. per hour from room not counting ventilation. | Heat loss counting exposure. | Per cent. added. | Cubic feet of air needed per hour as a heat carrier. | No. of registers installed. | Total net area of registers in sq. in. | Size of registers in inches. | Size of stack in inches. |
|---|---|---|---|---|---|---|---|---|---|
| 1.... | 1 | 51,520 | ..... | ..... | 40,185 | 2 | 322 | 13 x 20 | 13 x 13 |
| 2.... | ¾ | 74,200 | ..... | ..... | 57,876 | .. | ... | ..... | ..... |
| 3.... | 1½ | 29,400 | ..... | ..... | 22,932 | 1 | 184 | 17 x 18 | 17 x 13 |
| 4.... | 1½ | 36,260 | ..... | ..... | 28,283 | 1 | 226 | 17 x 21 | 17 x 13 |
| 5.... | 1½ | 42,210 | ..... | ..... | 32,923 | 1 | 263 | 17 x 25 | 17 x 13 |
| 6.... | 1½ | 35,350 | ..... | ..... | 27,573 | 1 | 220 | 17 x 21 | 17 x 13 |
| 7.... | .. | ..... | ..... | ..... | ..... | .. | ... | ..... | ..... |
| 8.... | 1½ | 16,520 | ..... | ..... | 12,885 | 1 | 103 | 13 x 13 | 13 x 8 |
| 9.... | 1½ | 16,520 | ..... | ..... | 12,885 | 1 | 103 | 13 x 13 | 13 x 8 |
| 10.... | 1½ | 42,210 | ..... | ..... | 32,923 | 1 | 263 | 17 x 25 | 17 x 13 |
| Totals. | .. | 344,190 | ..... | ..... | 268,466 | .. | ... | ..... | ..... |

TABLE II.

FIRST FLOOR DATA SHEET.

| Room. | n | Heat loss in B.T.U. per hour from room not counting ventilation. | Heat loss counting exposure. | Per cent. added. | Cubic feet of air needed per hour as a heat carrier. | No. of registers installed. | Total net area of registers in sq. in. | Size of registers in inches. | Size of stack in inches. |
|---|---|---|---|---|---|---|---|---|---|
| 11.... | 1 | 81,130 | ..... | ..... | 63,281 | 2 | 506 | 17 x 24 | 17 x 13 |
| 12.... | ¾ | 115,430 | 126,973 | 10 | 99,039 | 4 | 792 | 17 x 18 | 17 x 13 |
| 13.... | 1½ | 40,500 | 44,583 | 10 | 34,775 | 1 | 278 | 17 x 26 | 17 x 13 |
| 14.... | 1½ | 55,370 | 60,907 | 10 | 47,507 | 2 | 380 | 17 x 18 | 17 x 13 |
| 15.... | 1½ | 63,840 | 70,224 | 10 | 54,775 | 2 | 438 | 17 x 21 | 17 x 13 |
| 16.... | 1½ | 48,440 | 50,862 | 5 | 39,672 | 1 | 317 | 17 x 30 | 17 x 13 |
| 17.... | 1 | 51,940 | ..... | ..... | 40,513 | 2 | 324 | 13 x 20 | 13 x 13 |
| 18.... | 1½ | 23,660 | 24,843 | 5 | 19,377 | 1 | 155 | 13 x 20 | 13 x 13 |
| 19.... | 1½ | 23,660 | ..... | ..... | 18,455 | 1 | 148 | 13 x 20 | 13 x 13 |
| 20.... | 1½ | 63,840 | ..... | ..... | 49,795 | 2 | 398 | 17 x 18 | 17 x 13 |
| Totals. | .. | 540,100 | ..... | ..... | 467,189 | .. | ... | ..... | ..... |

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TABLE III.

SECOND FLOOR DATA SHEET.

| Room. | n | Heat loss in B.T.U. per hour from room not counting ventilation. | Heat loss counting exposure. | Per cent. added. | Cubic feet of air needed per hour as a heat carrier. | No. of registers installed. | Total net area of registers in sq. in. | Size of registers in inches. | Size of stack in inches. |
|---|---|---|---|---|---|---|---|---|---|
| 21.... | 1 | 81,130 | ..... | ..... | 63,281 | 2 | 506 | 17 x 24 | 17 x 13 |
| 22.... | 1 | 17,150 | ..... | ..... | 13,377 | 1 | 107 | 13 x 13 | 13 x 8 |
| 23.... | 1 | 103,460 | 113,800 | 10 | 88,764 | 2 | 710 | 21 x 28 | 17 x 13 |
| 24.... | 1 | 17,150 | ..... | ..... | 13,377 | 1 | 107 | 13 x 13 | 13 x 8 |
| 25.... | 1 | 31,900 | 35,189 | 10 | 27,447 | 1 | 220 | 17 x 21 | 17 x 13 |
| 26.... | 1 | 48,580 | 53,438 | 10 | 41,682 | 2 | 333 | 13 x 20 | 13 x 13 |
| 27.... | 1 | 93,030 | 102,333 | 10 | 79,819 | 2 | 638 | 17 x 30 | 17 x 13 |
| 28.... | ½ | 28,420 | ..... | ..... | 22,163 | 2 | 177 | 13 x 15 | 13 x 8 |
| 29.... | 1 | 37,380 | ..... | ..... | 29,156 | 1 | 233 | 17 x 21 | 17 x 13 |
| 30.... | 1 | 54,110 | ..... | ..... | 42,206 | 2 | 338 | 13 x 20 | 13 x 13 |
| Totals. | .. | 598,961 | ..... | ..... | 421,272 | .. | ... | ..... | ..... |

## DISCUSSION.

Prof. J. D. Hoffman: This paper is presented, gentlemen, not to give you anything startling, but to show that the work of design for the heating and ventilating engineer is open to a rational basis for calculation. Sometimes it is said, and I think said unjustly, that the subject of heating and ventilation is one which is purely guesswork. I rather like the statement made by Professor Johnson this morning, when he said, "It is *now* one of the exact sciences." One who has much contact with the different classes of design, not only in the line of heating and ventilating work, but in the line of machine design, engineering design and the like, will find that there is no one line of work which is so open to a rational basis of calculation as the subject that we are now considering, the subject of heating and ventilation. I have not attempted in this paper to make it complete; that is, to take up all the minor details of the system; neither have I tried to bring in such important features as washing of the air, but I have taken the most essential features of a plain and simple design and worked it out for the purpose of illustrating how it may be done.

Vice-President Mackay: Gentlemen, this paper is now before you for discussion. There are a good many good features here which should provoke discussion. Have you anything to say on this, Mr. Lewis?

Mr. Lewis: I think the practice I have had has been very

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closely in accordance with this. Possibly we get our boilers too big. We ordinarily use thirty pounds of steam per hour as the divisor to get the horse-power. We get enough power this way to take care of poor draft, poor coal or poor firemen. We know that we are safe. We have never got down to the limit of the size of the boiler.

Professor Allen: There are one or two points I would like to call attention to in this paper. In check No. 1 Professor Hoffman assumes a transmission of 4.7 B. T. U. per square foot per degree difference. One thing that must be taken into consideration in a fan system is the rate of air passage through the coil. The amount of condensation depends upon the rate of air passage; in addition, condensation depends upon the depth of the fan coil. I have obtained by actual experiment condensation as high as seven pounds per square foot with zero outside and a coil two pipes deep. Shallow coils are very efficient. On the other hand, the use of a very shallow coil is objectionable. Professor Hoffman states the coil was sixteen pipes deep. The use of a very shallow coil results in hot and cold spots, as the air comes through slowly in some places, in others rapidly, and there are unequal heating effects in the fan chamber.

I notice he uses as the speed of air passing through the fan coil 750 feet per minute. That is rather lower than my own practice. I bring this up as a matter of information. Possibly I have used too high speed, 1,200 feet per minute, as the speed in passing through the coil. This is calculated from the free air space between the coils. Of course, I can readily realize that the lower the speed through the fan coils the less power required to drive the fan. Professor Hoffman figures the horse-power of the fan on the basis of one ounce pressure. That seems to me rather high in an ordinary building. My experience has been that it is not necessary to use much over three-tenths ounce to half an ounce for overcoming resistence of the building. One ounce pressure would bring the horse-power to drive the fan rather higher than necessary in this case.

Mr. Lewis: My experience has been to use a velocity of 1,000 to 1,100 feet, in some instances 1,200 feet, through the coils.

Vice-President Mackay: What has been your experience, Mr. Larson, in regard to the velocity of air through the coils?

Mr. Larsen: I have used 1,200, as near as I could get it.

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Mr. Lewis: Professor Carpenter, in his book, gives a table of condensation which I have never been able to prove was not right, though I have used it several years. I think he gives 93-100 pounds per square foot per hour condensed, with entering temperature zero, with coils twenty rows deep. So, I think, figuring the amount of condensation as one pound per square foot per hour is good practice.

Vice-President Mackay: Professor Hoffman got a little better than that, I understand.

Professor Hoffman: 1.1.

Vice-President Mackay: That checks closely. What have you to say, Professor Hoffman, about the velocity?

Professor Hoffman: Of course, you understand I am situated in my work somewhat differently from you gentlemen, in that I am dealing with students and must show them the safe side of the condition every time, and the 750 feet per minute was considered a minimum velocity. If our system is in error at all, it is such that it gives larger ducts and thereby increases the capacity of the system. The co-efficient mentioned, i. e., 4.7, is given as the co-efficient where one is dealing with the coils in banks, sixteen or twenty rows deep; the other, i. e., 7, is for a shallow coil, say one, two or three rows deep, showing that the rate of transmission falls off decidedly with an increase in the number of rows of the coils. In fact, it is said that beyond twenty rows it is almost of no value to increase the number. Concerning the one-ounce pressure in the air line, this probably represents good working conditions for fans operating on such a heating system on a cold day.

Mr. Lewis: There is one thing I might mention in the practical installation of a blast steam plant. Instead of drawing through a separate tempering coil at the fan inlet and discharging part of the air through heating coils, thus getting two temperatures, one about 70 degrees and one about 130, I think it is more economical to put all the coils in one group and blow through them and then temper the air by a double damper, the same as admitting air to one room in the building. In the operation of the plant through much of the year, the six rows of pipe put in as tempering coils, practically one-third of the heating surface, are too much to heat the air to 70; they heat it to 100; and therefore the dampers are held open, taking longer

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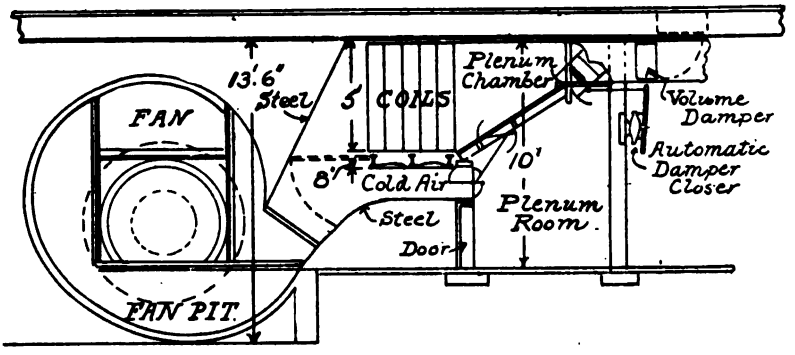
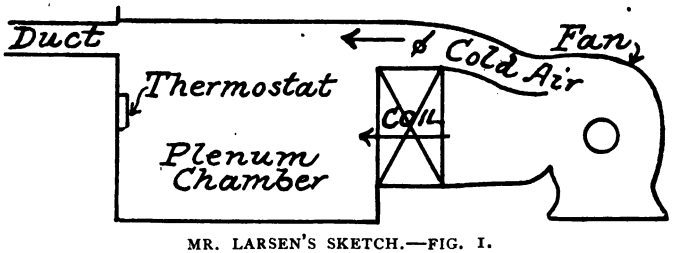
to warm the building. The admission of air is as easily controlled by two dampers, one admitting hot air into the tempered air chamber and the other admitting cold air into the tempered air chamber. (See sketch.)




MR. LEWIS'S SKETCH.

Mr. Larsen: My experience in Duluth has been the reverse, possibly on account of our having colder weather than you have been used to. I find by putting my coils all into one bank, and dividing my plenum chamber and using a double mixing damper at the flue, that when the thermostat throws the damper over to the cold side, the air coming into the room over the register immediately comes down and strikes the pupils. It is not up above the breathing line, where it ought to be; therefore I have placed my tempering coils outside of the fan to heat to 60 or 65 degrees; and that passes by the main heater coils into the lower part of the plenum chamber, and when the room goes to 70 degrees or over, the damper is turned and it admits the air at 60 or 65 degrees and does not strike the pupils at the breathing line so soon, or as forcibly as if it were allowed to enter at a lower temperature. Fig. 1 would be a good arrangement for mixing air if no tempering coil is used.




MR. LARSEN'S SKETCH.—FIG. 1.

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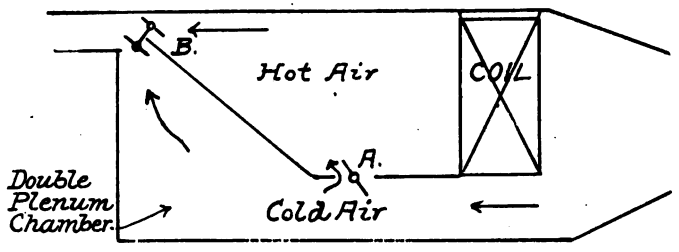
My experience is that there is less resistance underneath the chamber than when it is open, and consequently the cold air will go up in place of the hot air coming down.

Mr. Lewis: Not if you equalize it sufficiently.

Mr. Larsen: Fig. 2 shows this. The damper referred to is shown at A.




MR. LARSEN'S SKETCH.—FIG. 2.

Professor Hoffman: Has Mr. Lewis found in his practice that coils banked all in one bank are as efficient as coils split up? It occurs to me that when the coils are separated the air has a chance to get at the coil more completely all around and makes it more efficient. Has he found this point to be worth considering?

Mr. Lewis: The only way there can be any increase in efficiency would be that after the air leaves the tempering coils in passing through the fan it might lose a little heat, and thus might condense a trifle faster on impact with the heating coils. It makes no material difference whether the tempering coil is set at the fan inlet or outlet. The air has to go through twenty rows of pipe just the same.

Vice-President Mackay: That looks reasonable, but I do not know how it makes any difference in practice.

Mr. Lewis: In practice, two sections would be set together outside. By having the tempering coil separate from the heating coil, you do get better impact on the heating coil, that is all. I do not think you could measure the difference between the two.

Professor Allen: I have used a somewhat different scheme to overcome the same thing, using tempering coils and heating coils separately with the blast system. The first set of coils is turned on at about 50, the next set of coils at about 30 and the last set of coils at about 10 degrees. This system, of course, is probably more expensive to install.

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Vice-President Mackay: The turning on of the separate coils is done by hand, I suppose?

Professor Allen: It is done automatically by a system of temperature control. There is an objection to the control of the coils in this way, that is, it is apt to hammer when only one coil is on, but when the front section is kept warm by the section back of it, this hammering is prevented.

Mr. Lewis: This comes back to the thought I had in the first place, that by having outside control on the tempering coils in mild weather part of the investment is lying idle; if you could use that to heat the building up so much quicker when you start, you would gain more, that is all.

Vice-President Mackay: Your idea is to dispense with the tempering coil?

Mr. Lewis: Yes.

Vice-President Mackay: Is there anything in the air striking the fan at a very low temperature? You take air in sometimes 10 to 20 degrees below zero.

Mr. Lewis: I imagine you would throw a little more air by the fan. The fan is possibly working at a little better efficiency.

Vice-President Mackay: Anything in the way of gathering frost on the fan?

Mr. Lewis: I never heard of any.

Professor Allen: The objection I have always had to passing very cold air over the fan is that this cold air cools the bearings and the oil in the bearing becomes very viscous. This increases the friction of the fan.

Vice-President Mackay: I have always assumed that the tempering coil was an advantage in that regard.

Mr. Lewis: It depends somewhat on the job. I have seen it where it was very desirable.

Mr. Donnelly: I had a case a while ago where we were circulating steam through a hot-blast plant. We found, if there had been tempering coils in, it would have been much easier for the attendant. I think it is barbaric to expect the engineer to go into the tempering chamber to look after anything. I know, in one instance, the engines were right in the cold air chamber, so that the attendant, having two engines to take care of, a lot of valves and everything to shut down the hot-air blast, said that he was not hired to get pneumonia.

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Mr. Larsen: I would like to ask Mr. Lewis where he would put an air washer if he was going to use a single coil?

Mr. Lewis: I wouldn't use it.

Mr. C. E. Oldacre (Toronto, Ont.): I would like to ask whether, in case of air 30 or 40 degrees below zero, it would not be better to use the tempering coil?

Mr. Lewis: I think if the fan were not located too far from the outside wall, thus necessitating long cold-air ducts, that a temperature of even 30 or 40 degrees below zero would not make it work less efficiently than the ordinary plant with separate tempering coils. There would be increased efficiency in this quick heating up in the morning.

Mr. Lewis: I do not see why there should be condensation on the fan. The fan is the same temperature as the air coming in. I do not think there would be condensation there.

Mr. Samuel Kauffman (St. Louis, Mo.): Where would you put the air washer if you did put one in with this system?

Mr. Lewis: I could not use it with this system.

Mr. Kauffman: Why not?

Mr. Lewis: It would freeze the water.

Mr. Oldacre: Could you not put the washer between the heating and discharging coils on one side of the fan?

Mr. Lewis: There is very often a space of three feet left between the heating and tempering coils when they are all placed on the blast side of the fan. To some extent that is similar to this arrangement. I have never seen an air washer put on the blast side of the fan. I do not know any reason why it would not work, except there would be greater condensation of water and the air would be more moist; and the trouble with all air washers is that the air cannot be dried out. There is too much moisture in it. I think it is desirable, when washing air, to have the air as cool as possible before it enters the washer.

Professor Allen: My experience is that air washers must be installed with care and judgment. It is my practice to put air washers between the tempering coils and fans and heat the air after the fans. The reason for heating the air after the fan is to prevent the air carrying too much moisture into the room. If the air carries a large percentage of moisture on entering the room, the air in the room is colder than the objects in the room and is in danger of precipitation of moisture upon the objects in

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the room. If moist air is put into a room colder than the air, there is no danger of precipitation. I have one case in mind where air for a restaurant seating about 300 people is washed. This restaurant contains no outside windows, being a basement restaurant. In this case we have never had any difficulty from deposition of moisture. This is due to the fact that the air comes into the restaurant cooler than the objects in the restaurant, and we find that the air is heated on entering and never cooled. In this particular case we do not find it necessary to use our heating coils for heating and they could be entirely omitted, but where it is necessary to heat a room with incoming air, then heating coils should be introduced after the fan.

Mr. Lewis: There is one question I would like to ask for general information? When you put in an air washer, how are you going to get the water out of that air? Is there any method other than by heating that washed air? Would it not be possible to eliminate a large amount of the water evaporated into the air by blowing that air against a brine coil, at a temperature very much lower than the air, thus inducing condensation on that coil? I wonder if that has ever been tried?

Vice-President Mackay: Very likely that would be efficient.

Mr. Chew: Speaking about the cooling of air and the fact that no papers have come before this Society in reference to the New York Stock Exchange; probably that is the largest piece of air washing and cooling anywhere. Those interested in that phase of the question can look it up in *The Metal Worker* of August 5, 1905, and in *The Engineering Record*. They filter the air to get the dirt out and then cool the air to condense the humidity.

Vice-President Mackay: The idea is that the present washers carry considerable moisture in the process of washing, and the air absorbs this moisture, and unless there is some way of eliminating the moisture it is precipitated in the rooms as Professor Allen points out.

Mr. Kauffman: We made a test on a washer in the Public Library at St. Louis. It happened to be a Buffalo washer; we didn't have any guarantee as to the humidity and the precipitation that would come from it, but at about 3 degrees below zero, the coldest day that we had there, when we couldn't see outside on account of the moisture on the windows, it froze.

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## CLXXXI.

# THE COMBINED PRESSURE AND VACUUM SYSTEM OF STEAM HEATING.

GEO. D. HOFFMAN.

(Member of the Society.)

About five years ago there loomed on the horizon of the heating world a new system of vacuum steam heating, the vacuum being created by the condensation of steam within the apparatus instead of by mechanical means. Since then there has been a strong trend among progressive heating engineers toward this system of combined low pressure and vacuum steam heating in connection with gravity plants, and a number of representative firms are placing on the market special appliances as an aid to the heating contractor in the proper installation of such work. In view of these facts, it seems proper that this system of heating should be investigated by the American Society of Heating and Ventilating Engineers, and its advantages and limitations thoroughly discussed. It is more with this end in view than with any idea of presenting a technical description of this system that this paper is prepared. The term vacuum, according to the dictionary, means an empty space or a space void of matter, but when the term is used in connection with a steam apparatus, it signifies that means are employed to relieve the apparatus of air, and, by preventing its return, to create a condition under which steam will circulate at temperatures below 212 degrees.

Vacuum can be created in a steam heating apparatus by means of a pump, exhauster or other mechanical device for the removal or exhaustion of air, or by the condensation of steam within the apparatus. The method to be described in this paper is the one which creates the vacuum by first filling the entire apparatus with steam, expelling the air through vent

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ports by pressure, then preventing the return of air by special appliances when the pressure falls below that of atmosphere.

Many engineers contend, however, that vacuum thus obtained is very much like the proverbial greased pig which was turned loose in barn-raising days, a very slippery customer, but to the man who used plenty of rosin on his hands and trousers, the pig was easy; and so it is with the man who uses proper appliances for stopping the two biggest leaks in any apparatus; i.e., the stuffing box of the radiator valves and the venting valves. If he effectually stops these leaks, the rest is easy.

But admitting that the heating contractor who has installed such an apparatus has used approved appliances throughout and made it steam, water and air tight, what is the gain? With such an apparatus he can circulate steam throughout the system at temperatures both above and below 212 degrees, and by thus increasing the temperature range within the apparatus he can meet external weather conditions with such an even and equable indoor temperature as will take all the pang out of winter, and do it with a fuel economy that will surprise the uninitiated. Let us study the "Why and Wherefore."

The boiling or vaporizing temperature of water in an open vessel is 212 degrees at the sea level, the temperature falling as the altitude above the sea increases, or as the atmospheric pressure decreases. The boiling point of water under a nearly complete vacuum, or a vacuum of 28 inches of mercury, is 100 degrees, and as water will not boil under an atmospheric pressure of 14.7 pounds (sea level pressure) until its temperature reaches 212 degrees, it proves conclusively that it is pressure and pressure only that determines the temperature at which water boils. To still further demonstrate this fact, the writer has pumped ten pounds of air pressure on a sealed system and then raised the temperature of the water to 240 degrees before there was the slightest sign of ebullition in the water. On another occasion, with ten pounds pressure on the system, he raised the temperature to 230 degrees and then extinguished the fire and reduced the pressure by opening a vent cock. As soon as the gauge pressure indicated six

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pounds, the water began to show signs of life, and when the pressure indicated five pounds it was boiling violently.

But how is vacuum created in a steam heating system without mechanical means?

Steam is water in a gaseous state, occupying, when at ordinary atmospheric pressure, a space nearly seventeen hundred times as great as the water from which it originates; or, in other words, a cubic inch of water when converted into steam, if unconfined, occupies a space equal to about seventeen hundred cubic inches or about one cubic foot. When the conversion of water into steam takes place within an enclosed space, for instance, a steam heating apparatus, if the different parts of the apparatus are properly proportioned, the steam would fill the space in the apparatus not occupied by water were it not for the fact that this apparently unoccupied space is in reality fully occupied by air.

Steam and air being of different density will not mix, and the result is when steam is generated there is simply a pushing or compressing of the air into the pipes and radiators as the steam pressure increases. In order to allow the steam to circulate into and through all the pipes and radiators, it is therefore absolutely necessary to provide an outlet for the air, or what is commonly called an air valve or vent, on every radiator or heating coil connected with the boiler. When the air has been entirely expelled from the apparatus by pressure of steam, the apparatus may be said to be full of steam. When the steam is again condensed to water, the space occupied by the steam will be left a void or vacuum, provided the air is prevented from returning into this space. If the condensation of steam or water were instantaneous, there would be little to recommend the vacuum system of steam heating on gravity plants; but the fact is that the condensation and loss of heat is gradual and can be checked and held, provided there are no air leaks in the apparatus, at any point between atmospheric pressure with a temperature of 212 degrees and a nearly complete vacuum, say 29 inches, with a corresponding temperature below 80 degrees, by simply maintaining the strength of the fire at a point where the heat units delivered by the fire equals the heat loss from the apparatus. The various degrees of vacuum and pressure and

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the corresponding boiling temperature of water between 29 inches of vacuum and 10 pounds pressure are shown in the following table:

| Vacuum Gauge, inches of Vacuum. | Tem. of Steam or Boiling Point of Water. | Vacuum Gauge, inches of Vacuum. | Temp. of Steam or Boiling Point of Water. |
|---|---|---|---|
| 29.19 inches. | 70 degrees Fah. | 9 inches | 194 degrees Fah. |
| 28.51 " | 90 " " | 8 " | 196 " " |
| 28. " | 100 " " | 7 " | 199 " " |
| 27 " | 114 " " | 6 " | 201 " " |
| 26 " | 125 " " | 5 " | 203 " " |
| 25 " | 133 " " | 4 " | 205 " " |
| 24 " | 140 " " | 3 " | 207 " " |
| 23 " | 146 " " | 2 " | 208 " " |
| 22 " | 152 " " | 1 " | 210 " " |
| 21 " | 157 " " | 0 (atmosphere) | 212 " " |
| 20 " | 161 " " | Steam gauge Pounds pressure | |
| 19 " | 165 " " | 1 pound | 215 " " |
| 18 " | 169 " " | 2 " | 219 " " |
| 17 " | 172 " " | 3 " | 222 " " |
| 16 " | 175 " " | 4 " | 225 " " |
| 15 " | 178 " " | 5 " | 227 " " |
| 14 " | 181 " " | 6 " | 230 " " |
| 13 " | 184 " " | 7 " | 232 " " |
| 12 " | 186 " " | 8 " | 235 " " |
| 11 " | 188 " " | 9 " | 237 " " |
| 10 " | 191 " " | 10 " | 240 " " |

It is apparent from a study of the above tables that if any particular pressure either above or below atmosphere is maintained in a steam heating apparatus that steam at the temperature corresponding to that particular pressure can be circulated throughout the entire apparatus, provided the same is absolutely air tight and all air has been previously expelled from the apparatus. It is also apparent from a study of the above table that air is the great enemy to be contended with in connection with this particular system of heating. When operating a plant below atmospheric pressure, air exerts a constant steady pressure (equal to one-half pound for every inch of vacuum indicated) on every part of the apparatus, including radiators, pipes, fittings, boiler and boiler trimmings both above and below the water-line in the boiler. Give it the slightest chance, even to the extent of a pinhole in the left-hand lower corner of the boiler, and air will force its way into the apparatus and eventually kill the steam and steal whatever heat is in the radiators. Air, when it once gets a foothold, holds its position until it is driven out by force, that force in the system under discussion being steam pressure.

It is plainly evident from the foregoing that if it was not for

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air in the system, steam or vapor would begin to circulate through the radiators at 70 degrees, and every degree of heat added to the water in the boiler would mean an added degree to the heat in the radiators. If it was not for the air in the system it would be possible to have a range of temperature within the apparatus of from 70 degrees (the boiling or vaporizing temperature of water under 29.19 inches vacuum) to 240 degrees, the temperature under ten pounds pressure.

Admitting this to be a fact, it is only logical to presume that any method of installation which would have for its object keeping the air out of an apparatus after it is once gotten out, would be worthy of serious consideration.

There are always two factors of waste in any steam heating apparatus or in fact in any heating apparatus, first, overheating of the room beyond the temperature required for comfort; and, second, the chimney waste. The elimination of these wastes or their curtailment means fuel economy, and this is the goal sought by all systems. Keeping the air out by other means than the pressure of steam is surely an economy of heat energy and a step in the right direction.

While it is an admitted fact that it is a physical impossibility to so construct a steam heating apparatus as to make it absolutely air tight against vacuum pressure, still it is possible to so construct and install a combined pressure and vacuum system of steam heating as to insure for limited periods of time a temperature range within the apparatus of 75 to 100 degrees (from 140 to 240). This flexibility of control gives the intelligent operator the means of properly utilizing the fuel used with a minimum waste. It is evident that it cannot acquire as much fuel to heat water to a temperature of 160 degrees Fahrenheit as it would to heat it to 212 degrees. If, therefore, the outside temperature only required an inside radiator temperature of 160 degrees to maintain the desired heat in the building, it follows that a smaller amount of fuel can be used, provided steam can be generated and circulated at 160 degrees. In order to be able to present some accurate data on the question of fuel economy in connection with this system of heating, the writer installed a small plant of four radiators in which gas was used as a fuel. The following table shows the consumption of gas per hour under pressure and vacuum, the temperature of

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the room in which the radiators were placed being maintained at 70 during the test.

| To maintain a steam temperature of | Required the consumption of | The gauge registering |
|---|---|---|
| 212 degrees | 60 feet gas per hour | — atmosphere |
| 201 " | 50 " " " " | 6-in. vacuum |
| 190 " | 39 " " " " | 10½ " " |
| 180 " | 29½ " " " " | 14½ " " |
| 172 " | 27½ " " " " | 17 " " |
| 157 " | 24 " " " " | 21 " " |

In the above test when the outside temperature was sufficiently cold to demand 212 degrees of steam heat in the radiators, it required 60 feet of gas per hour to maintain this temperature, but as the outside temperature moderated a corresponding lower temperature of steam (calling for a less consumption of gas) was required in the radiators, until it reached a point when only 157 degrees of steam and a gas consumption of 24 feet per hour was required to maintain the room temperature at 70 degrees. Another test was made (at a time when only 157 degrees of steam was really required to maintain the room temperature at 70 degrees) of consuming 60 feet of gas per hour and maintaining a steam temperature in the radiators of 212 degrees with the result of raising the room temperature to 85 degrees. The 15 degrees surplus heat was thus maintained at a cost of 26 feet of gas, and as the 15 degrees of heat was not needed, the fuel or gas thus used unnecessarily was wasted. With the ordinary steam job it is necessary to have 212 degrees of steam heat in the radiators in order to have any heat at all. In the hands of an intelligent operator, provided the system is reasonably tight, it is possible to practically do away with the overheating evil attending the use of the ordinary steam apparatus by enabling the operator to circulate just the required degree of steam throughout the apparatus necessary to maintain the desired temperature in the heated room. Hold fast to that which is good is a trite saying but also an axiomatic truth. To hold steam even at a lower temperature than 212 degrees in the radiator on a cold winter's night is surely holding a good thing, and it is also surely a common-sense proposition to keep air out of an apparatus as long as possible, after it has

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been once gotten out by the expenditure of fuel energy. The advocates of the combined pressure and vacuum system of steam heating claim that the advantages over the ordinary system of steam heating are:

*First.*—A range of temperature between 140 and 240 degrees within the apparatus, to suit any external temperature.

*Second.*—Economy in fuel. During the ordinary weather the fire can be banked for hours and still a sufficient heat circulated through the radiators to maintain the temperature in the living rooms at the proper degree.

*Third.*—Economy and labor, as less fuel is consumed and less labor is necessarily expended in the care of the apparatus.

*Fourth.*—The great physical comfort of the inmates of a building so heated, because of the fact, if properly controlled, the heat is always just right, no matter what the outside temperature may be.

The advantages of this system of heating over hot-water heating are:

*First.*—Low cost of installation, the cost of installing a vacuum system of combined pressure and vacuum heating being but little more than the ordinary steam system, and therefore very much less than hot water.

*Second.*—Economy in fuel. With a hot-water apparatus a quantity of water is required to fill the entire system, boiler, pipes, radiators, etc., being at least twenty times as much as required in the vacuum system of steam heating. In a vaccum system of steam heating it is steam circulating through the pipes and radiators which carries and distributes the heat of the fire to the various parts of the building, while in a hot-water apparatus it is the water itself which carries and distributes the heat. The velocity of the water travel is comparatively slow; while steam travel, especially in vacuum, is almost as rapid as thought itself. The quickness of results, or what might be termed the flexibility of a vacuum system of steam heating, enables the operator at all times to have just the right amount of heat in the radiators to maintain the desired temperature, and thus prevent the waste of fuel incidental to overheating.

*Third.*—Economy in space required for the radiators. As a much higher temperature can be maintained in the radiators in a combined pressure and vacuum system than in hot-water

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radiators, it is evident that less radiation and therefore less space is required.

*Fourth.*—All danger from leaks in the combined pressure and vacuum system of steam heating is practically done away with.

Another great advantage of the combined pressure and vacuum system of steam heating is the fact that by use of the approved appliances now on the market this system can be easily installed on any system of low-pressure steam heating old or new, insuring for its user the acme of comfort combined with a fuel economy of from 20 to 40 per cent. over the more common methods of steam heating.

## DISCUSSION.

Mr. William G. Snow: I am interested in the statement near the foot of page 227, where it states that "It is possible to so construct and install a combined pressure and vacuum system of steam heating as to insure, for limited periods of time, a temperature range within the apparatus of 75 to 100 degrees." Can Mr. Hoffman give us any idea of what constitutes these limited periods; that is, in a general way, what would be considered a reasonable limit during which that range in temperature could be maintained?

Mr. G. D. Hoffman: I know nothing about this matter personally, that is from personal tests. I have to take the statement of our customers, and also men like Mr. James Mackay, as to how long periods they can maintain their apparatus under vacuum, but I have been told that the period depends, of course, first upon the tightness of the job, and, second, upon the coldness of the weather. Sometimes the operator does not want to run the apparatus under vacuum, and if it is automatically controlled by a temperature regulator the periods of vacuum or pressure will be determined by the thermostat. Generally speaking, however, from ten to twelve hours under vacuum is considered very good practice; or, in other words, to get up to steam pressure twice during the day.

I have one party in mind in St. Louis who claims that his customer ran his apparatus under vacuum for three days. I know nothing further than his mere statement to that effect—and that all that time he kept his house comfortable.

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Mr. Edmund F. Capron: In making this test, was the gas supply controlled by an automatic regulator?

Mr. Hoffman: No; we had a tested meter in the same room with the apparatus, by the side of the boiler, and we simply took periodical readings, ranging from a half hour to an hour, and determined the amount of gas that was being used in that way.

Mr. Capron: What controlled the supply of gas? How was it shut off?

Mr. Hoffman: It was controlled by hand.

Mr. Capron: You show a great saving in the consumption of gas in this case. Could you regulate the coal to make the same saving in consumption; would the coal burn up so rapidly that you couldn't shut it off as rapidly as with gas?

Mr. Hoffman: You can.

Mr. Weinshank: Does this system hold good for all systems or only for small house heating? In cases using exhaust steam, would this system be applicable? Now, isn't it a fact that this system is only applicable to small house heating, dwellings, etc.?

Mr. Hoffman: We have never tried any of our special appliances on exhaust steam heating, and the reason why we have not done so is simply owing to the oil and grease which naturally come from the engine, sooner or later stopping up the operation of the valves; but I have never been able to figure it out myself why the principle would not be applicable to an exhaust system, provided you had some means of controlling the return of air to the radiator after it was once expelled. Of course, in that case you would either have to, once or twice a day, have sufficient back pressure on your engine to exhaust the air by pressure instead of by suction, or else you would have to have your live steam connected up in such a way that you could get this necessary pressure; but when you speak about small jobs—dwelling houses—I would like to state that we have an installation in New York on a seven-story apartment building that has over 300 rooms in it. We have a recording pressure gauge connected to the boiler, and a number of charts were taken off the recording gauge, which showed that only twice in the twenty-four hours did the boiler ever go to pressure. That was in the morning and evening. All the rest of the time, during the day and also all during the night, the apparatus was working under vacuum.

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Now, in this particular case, there are over 160 rooms in the building which are heated by risers running up through the rooms, and requiring, therefore, only one control on the top of that riser—there are twenty-four of those risers and twenty-four controlling valves which control those risers. That man paid us in the neighborhood of $300 for the equipment necessary to put his job under vacuum. He claims, and says he is willing to make an affidavit if we wish him to do so, that his coal saving was over $400; so that he paid for the vacuum proposition and had $150 to spare.

Secretary Mackay: During what period?

Mr. Hoffman: One winter.

Mr. Donnelly: I am very much interested in this paper of Mr. Hoffman's. Here is something I ran across a while ago in Robert Briggs' "Steam Heating—An Exposition of the American Practice of Warming Buildings by Steam." Mr. Hoffman says:

"About five years ago there loomed on the horizon of the heating world a new system of vacuum steam heating."

I would like to read a little from Briggs. He says:

"The application of steam to the warming of buildings in the United States originated with the late Mr. Joseph Nason, of Boston and New York, who died six or seven years ago. . . . He enjoyed the advantage of having been for a short time a pupil of Jacob Perkins, in London, about 1840; . . . and with the maturing of the system are associated the names of Mr. J. J. Walworth, of Boston, brother-in-law and partner of Mr. Nason; Mr. Gregg, of New York; Mr. J. O. Morse, of New York, by whom, amongst others, was introduced the method of closed circulation for working a steam below atmospheric pressure."

So that if we take Briggs' book as an authority, which was written back in 1870, Mr. J. O. Morse, of New York, introduced the system prior to 1860 of working below atmospheric pressure.

On the first page Mr. Hoffman says: "A vacuum can be created." That is different from any other creation, because usually when you create something you make something, and this is a production of nothingness, so to speak. (Laughter.) I think the term is a little vague. Vacuum may be obtained, and

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there are two things in connection with vacuum which I think we want to get clear so as to be practically correct.

We first use means to obtain a vacuum or to obtain a reduction in pressure. Then we may use entirely different means to maintain that lower pressure. For instance, in an apparatus we obtain the original vacuum by removing the air, or the greater part of it. We may obtain that vacuum by means of a pump, but we do not afterwards maintain it by the pump. We use the pump afterwards to remove the water and air as it accumulates, but the maintaining of the vacuum is due to the condensation of steam.

Now, on page 227, in regard to this test, it says: "In order to be able to present some accurate data." I think this paper would be much more valuable if it were based upon an actual commercial installation, that is, some plant that has been installed and not simply a testing plant or a laboratory plant. I cannot reconcile these data with the facts. I hope they are true. I would like to produce some of the results myself.

When the radiator was 212 degrees it burnt sixty feet of gas per hour. When the radiator was 201 degrees it burnt fifty feet of gas per hour. When the radiator was 157 degrees it burnt twenty-four feet of gas per hour, which was within one-half of the actual amount of fuel. According to all data I have been able to get, a radiator at 180 degrees will give off fully two-thirds the amount of heat that a radiator at 212 degrees will give off. So this gives off two-thirds the heat with one-half the fuel. I am a little afraid that is too much saving.

I do not know how long a period of time these tests occupied; but if they were started on moderately high temperature and came down during moderate periods of time, you would get an apparent saving from the heat stored up in the pipes, iron and other parts of the apparatus. Then if you started with low temperature and went up in successive periods of time, you would have a continuing accumulating loss due to the absorption of heat by the iron parts of the apparatus.

In speaking of different temperatures, I recently figured out the amount of vacuum necessary, or temperature necessary, to maintain in radiators to correspond with outside weather of different temperatures, starting with the supposition that the radiation installed in a room is sufficient to maintain 70 degrees in

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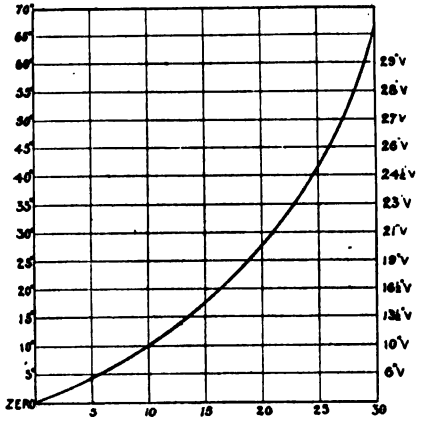
zero weather, and it figures out that when the weather is 20 degrees outside you must maintain 16½ inches of vacuum. When the weather gets to 40 degrees, 24½ inches of vacuum; when it is 50 degrees, 27 inches.

Some cuts have been published of a curve plotted from these figures, which may not be exactly correct in practice, but it is theoretically very close to it, and I consider these very low vacuums somewhat impossible. I have made some trials, with attempts to run house-heating apparatus under a vacuum. In fact, I have one in my own house and I have put several in other places and attempted, in a different manner, to see what the maximum vacuum was obtainable, and I made up my mind that vacuums below 12 or 15 inches were difficult to get and much more difficult to keep. (See plotted curve.)




MR. DONNELLY'S CURVE.

As to the question by Mr. Snow, as to the length of time a vacuum might be obtained, we have so many periods of weather when the thermometer is 35 or 50 degrees, we certainly would have to maintain 15 or 20 inches of vacuum, and that is the most important time. If you can make a saving at all, you can make your biggest saving, of course, in the mildest weather, and then we have to maintain the lowest vacuum. I consider that it was possible to make a considerable saving along the line of vacuums, but it was possible to do it in another manner, with very much less trouble, on account of the mechanical difficulties involved in the problem. In the ordinary gravity steam

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apparatus I have always called it the "spot system." Take a private house, entirely open. They have one radiator turned on in one location and the others shut off. They heat the building in spots and let the hot air diffuse. I admit if you combine the vacuum and the spot system you can get better results, because you can leave more radiators on and you will not heat in a few spots. There is some advantage in that. I would like Mr. Hoffman to tell us if it is not true, even with the best systems, with the lowest vacuum obtainable, that some radiators are not generally shut off in mild weather, which are not used except when it is quite cold; so that the apparatus, as it is run by the people as they have it in their houses, is a combination of spot heat and vacuum heat.

Now, I want to ask something about damper regulation. Assuming we coal up a boiler in the morning; the vacuum has been lost during the night; with 16 or 18 inches of vacuum the draft is under certain control; if we fire up as soon as we get that vacuum we will shut off the draft too quickly. We have to regulate the pressure and regulate the air and hook up the damper and shut off again. I want to know what Mr. Hoffman's damper regulation is for these systems.

Mr. Hoffman also speaks of temperature regulation. I would like to ask him in what manner automatic temperature regulation has been applied to these systems of vacuum heating.

Mr. Hoffman: Two of the most successful jobs, and two of the most successful users of our special appliances combine the apparatus with the Johnson system of temperature control as applied to the dampers of the apparatus. It has not only been my own personal observation, but it is the observation of the particular parties who are using the appliances connected up in this way and controlled in this way that only part of the radiator is heated in very mild weather; and even under this condition the gauge will frequently indicate 10 or 15 inches of vacuum. Each radiator may have from 1 to 5, 6, 7 number of loops heated according to the temperature demand, so that in that manner we eliminate by that method what Mr. Donnelly terms "spot heating," by only partially heating each radiator.

I have in mind one customer who has automatic control in that way in connection with his dampers only. He leaves his house entirely open, and says, as far as his own observation goes, that

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there were days together that he never saw the gauge indicating pressure. This man is a practical steam-fitter and the apparatus is in his own house. Now, undoubtedly at some period of time, when he, possibly, was not there, the gauge did go to pressure; but he said his observation of it was that the gauge was always showing 5 to 15 inches of vacuum every time he went to the cellar to put on coal, and that is the only thing he ever did to the apparatus—put on the coal—as the thermostat took care of the dampers.

In regard to this matter of test, which Mr. Donnelly questions, as shown on page 227, I will say that the way I made this test was in a closed room. I would set the gas to flowing at a certain amount and maintain a certain amount of vacuum in the apparatus, and then I would control the windows in such a way that I maintained a temperature of 70 degrees in the room, operating it just the same as though it was the outside, because that was controlling the loss of heat in the room. I simply raised or lowered the window until I got it at such a point that 70 degrees would be maintained in the room. "As the outside temperature moderated, a corresponding lower temperature of steam (calling for a less consumption of gas) was required in the radiators, until it reached a point when only 157 degrees of steam and a gas consumption of 24 cubic feet per hour was required to maintain the room temperature at 70 degrees. There would be 157 degrees in the radiator and 24 feet of gas per hour, which was the meter reading, and 21 inches of vacuum, which was the gauge reading, and that would run all day. We watched it very closely; in fact, very seldom left the room during these tests; so that we were sure the data employed here were accurate for determining these propositions.

In regard to Mr. Donnelly's criticism of my statement here, that about five years ago the vacuum system first came into prominence, I possibly did not mean exactly what I said here, that that was the first appearance of it. I might cite an instance of an old lady at Elizabeth, N. J., who was using common, ordinary compression cocks on her radiators. The steam-fitter, thinking that he was going to improve the apparatus for this lady, afterward got her to use some automatic valves in place of the compression cocks. About a week after she had bought the compression valves she came down and said: "I wish you

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would go to my house and take off those new fangled things you put on and replace them with the compression cocks." She said, "I find that I cannot hold the heat in my radiators anywhere near as long as I could when I was operating with the ordinary hand cocks, and, therefore, what you call an improvement is a detriment to my system." The steam-fitter was very much worried until one of our salesmen came along and explained that what the old lady was doing was operating her plant under vacuum. She was getting the results with vacuum.

There is no question but that, away back in the dim past, when hand-manipulated vent valves were practically the only things used, that low-pressure steam plants were operated under vacuum. But it was only about five years ago when it began to be vigorously pushed, and automatic appliances used, and that is what I meant by my statement.

Prof. J. H. Kinealy: Mr. President, I do not think the method of test of Mr. Hoffman's needs to be commended. But I see no reason why the paper should not be substantially correct, even though the amount of heat given out by the radiators should be out of proportion to the amount of fuel, as Mr. Donnelly says.

We know that it is a fact that the lower the temperature of the steam used for heating, the less steam will be required; and hence the less fuel. That has been determined by our own experience and by experiments and tests made years ago and being made every day. Only at the recent meeting of the American Society of Mechanical Engineers, at Indianapolis, there was a paper read by a gentleman from Boston in which he cited the results of experiments made, extending over a number of years, to determine the most economical method of heating warehouses. He did not use a vacuum system, but he used pressure, in one case between one and two pounds; in another case between 10 and 12 pounds, and, in the third case, between 15 and 17 pounds. He found his cost was least with the lowest pressure. If this gentleman had used a vacuum system and had carried his pressures below that of the atmosphere his cost would have been reduced even more.

I think that the vacuum system is the thing to be commended, and any method by which we can adapt a vacuum system of heating to ordinary houses is one that will be of benefit to all. I usually think of heating systems as belonging to one of two

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classes. The first class is that system by which the owner is made comfortable and the engineer is also made cool; the other is that by which the owner is made cool and the engineer is kept hot. (Laughter.) The vacuum system belongs to the first class.

Prof. Warren S. Johnson: On the principle of conservation of energy, in heating a room it does not make any difference in what way you get the units of heat. It takes so many units of heat to heat a room, which will cost the same amount. I cannot see what difference it makes whether the heating surface is 180 degrees, 250 degrees, or 300 degrees, or whatever it is, provided so many units of heat are put into the air of that room, and how the expense can be any different in one case than in another. It is well known that the pressure costs nothing. When pressure is once obtained in a boiler, whether it be one pound or 500 pounds, the pressure itself is inexpensive; there is no gain and no loss so long as it is maintained. If there is a loss, in running under high pressure, it must be because the water in the boiler and the steam in the boiler flues are hotter and that the gases going out the chimney are somewhat hotter than in running at low pressure. It would seem that all the coal you burn in a house gives you comfort, except what goes up the chimney. So to determine the efficiency of heating appliance is to determine the quantity and temperature of the gases that go out the chimney. All the rest is used; that is evident.

It would seem to me that the principal advantage of vacuum is to get the air out of the radiators, so that you may get them to work efficiently. A large part of their surface is affected by steam which is mixed with air; consequently they have not the real condensing surface that they would have if there was no air in the radiators, and they become inefficient.

It is evident if there were no air in a radiator, that a small radiator would answer the same purpose in a room as a bigger one partly full of air. The question would be the cost of original installation and the room it occupies. I have sometimes wondered why those who put in vacuum systems are, apparently, so parsimonious in the matter of the aspirator, or whatever they use to get the air out of the steam. It is well known that when a pump has once produced a vacuum it costs practically nothing to run it. No matter how big the pump, all the expense

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of running the pump is simply the friction of the pump, because when the air pistons move in the vacuum they do not perform any work, and I never could see why they did not put in a big pump, so as to be sure to use that vacuum, rather than a small one.

It seems to me that the trouble is that the valves placed on the return pipes, at the radiators or at the air valves, leak, and that the vacuum is destroyed by steam and not by the air. In other words, if these pipes would allow steam to get into the return pipes there would not be anything got out of the pipes, after 15 or 20 minutes, and keeping up the vacuum would cost nothing—let the pump run in the vacuum.

Some years ago it occurred to me that if the main valve on the radiator was shut, and if the air valve was shut too, then when the steam condensed there would be a vacuum by natural condensation, and I devised a system called "Hermetic Vapor System," by which each radiator is held on a vacuum. When the thermostat was shut the valve was also shut and the vacuum remained until the steam came on again. In that way each radiator is independent of the other, but producing no vacuum on the general system. Every radiator has a system of its own.

Mr. Hoffman mentioned the fact that only a few coils of the radiator in this system were heated, and not the whole. It is evident that in the vacuum all must be heated equally, and that is the advantage of a vacuum system. If, as Mr. Hoffman states, only some coils were hot, it was because there was not a vacuum, and the air in the radiator did not allow the steam to go to all parts. I have noticed, in a case where you shut the radiator off entirely, you will get, under ordinary circumstances, as high as 28 inches of vacuum. I have never known a radiator to keep less than 20 inches of vacuum. That must be because some air has either not gotten out or because of some little leak; but whenever the steam is turned on it goes instantly to all parts of the radiator, and if the steam is on, if less than a minute, every portion of the radiator will be equally warm.

If a vacuum system has the advantage of heating all the radiator thoroughly and quickly, it is evident that you can reduce the heating surface in the room, and my experience is that you can reduce the heating surface about 25 per cent. if you use a vacuum system, but not because it is a vacuum or because the

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temperature is less than 212. It is only because there is no air in there to prevent the usefulness of the radiator as a whole.

Professor Bull: I want to add my testimony to Professor Johnson's, and to emphasize as strongly as I can what Professor Johnson has said in regard to the question of economy. There are certain advantages connected with the vacuum system which I think everybody recognizes.

That it should take less heat to heat a room under the vacuum system, I am positively certain that it is not so. You may possibly use a small radiator; you may possibly use exhaust steam when you could not do it under ordinary circumstances; but if you have steam of one pound or 5 pounds, or 10 pounds pressure, as Professor Johnson says, it takes as much to heat. It is possible, in small individual plants, that if you fire in the evening, put a lot of coal in in the evening, that with a perfect vacuum system the steam will certainly last longer during the night than it would without the vacuum system, and in that respect it would be an economy; but not because the pressure is low.

Prof. J. D. Hoffman: I presume there is another cause of loss, too. It has been stated that the principal loss is the one up the chimney. We can all see that; but there is still another loss, i. e., through the opening of windows and doors to reduce the temperature of the room.

The chief thing to be desired in any heating system is to have a uniform temperature in the room all the time; this can only be had when we obtain a uniform circulation of the heating medium, whatever that medium may be. If by any means the system may be regulated to reduce the excessive fluctuations of the temperatures, we are improving our heating system, not only because it is more satisfactory to the people, but because it is more economical, as has been proven by tests. The alternate heating and cooling off of any building is productive of loss. If we can, by any means, produce in the steam system a longer circulation of the steam; that is, if we could run it further into the night, or if in the morning it would start up with a less consumption of fuel, this would naturally tend toward increased economy. Proper attention at the fire and proper regulation at the radiator will greatly improve the average steam-heating system.

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Professor Johnson: There is a system, which is a very old one, of allowing the steam going to one end of the radiator, to be open to the atmosphere at the other, by which, in opening this valve more or less, the radiator will, more or less, fill with steam; consequently you can grade the amount by the regulator. Wouldn't this overcome the same difficulty with every heated room, if you could grade the amount of steam in that way? Mr. Tudor, of Boston, as long as thirty years ago, devised a valve that was put in, in one instance, in the Board of Trade building of Chicago. There was a little dial and a pointer on top. By turning the wheel to 5,000, 6,000 or 12,000 you were supposed to get a certain amount of heat. The other end of the radiator was open into a pipe that had no pressure. This would heat one, two or three, or a number of other coils, as the weather would allow. Wouldn't we get as many units of heat in that case as in this case, when there was no vacuum at all—simply atmospheric pressure? There could not be pressure because the valve was opened into atmosphere, and there could not be a vacuum; but you simply got a certain amount of steam to give certain heat units to the room.

Mr. James H. Davis: The apparatus that Professor Johnson refers to was installed, but was never successful in operation and was removed after about two years' trial. It was also installed in several other buildings, none of which seem to have given satisfaction, and they were eventually removed from all of them. The Professor seems to think that under vacuum conditions it is impossible to only partially heat a radiator. I have seen a number of instances where for long periods of time only portions of the radiator were heated, but that was due to limiting the amount of steam that passed into the radiation, and I think it quite possible to so control your damper in a vacuum heating apparatus that the amount of steam generated will only partially fill the apparatus and radiators and thereby produce the desired results.

Mr. Donnelly: In regard to Mr. Johnson's remarks upon the Tudor system, I was in New York during some of the period of the Tudor development. Much of the trouble of the Tudor system was caused by the cutting of the inlet valve, which increased the opening of the radiator and after one or two seasons it would pass steam into the return pipe. The return pipe was

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open and it would waste steam. The further development of that system has been through Mr. Tudor and his son, in Boston. They have now put on the return of each radiator a thermostatic device to prevent that waste, and they have had considerable success. They are still troubled with some cutting in the valve and they have recently changed the valve to overcome much of it. At the same time some of us have been working to close up the return, and not have it open to the atmosphere. I have constructed an apparatus that will run as high as 10 pounds pressure and still push the air down the return under pressure, supplying only the steam to the return necessary to heat it. There are two ways of producing economy with radiators; either heat part of the radiator or heat the radiator at a lower temperature.

With Mr. Hoffman's apparatus, as far as I know, a restriction of the supply will cause accumulation of water in the radiator. With the Davis construction, a restriction of the supply does not cause an accumulation of water in the radiator. So it is not possible to operate Mr. Hoffman's construction to partially heat the radiators in the same way that they are heated with the construction that Mr. Davis speaks of.

Mr. Donnelly: I would like to say something on fuel economy. I believe that fuel economy, if any, comes from the same cause that it does with the economizer in high-pressure practice, that is, reducing the temperature of the flue gases. There is economy due to the reduction of the temperature in the gases, and that is the only economy possible. It is possible to produce heat from an apparatus with more economy the lower the flue gases are maintained, and, as Mr. Thompson said, a year or two ago, in Chicago, the hot-air furnaces would really reduce the flue gases lower than any other heating method we had; but there are other wastes.

It is not only necessary to produce the heat economically with very little loss, but, I think, it is more important to use it with very little loss; and, again, there is the economy Mr. Hoffman speaks of, using the heat with less loss, less opening of windows. There is the economy due to not wasting it after it is produced; and, other things being equal, I believe that the system which produces the least loss in use will be the most economical in the end.

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Professor Allen: There is a most apparent economy which the vacuum system gives. I must agree with Professor Bull that there cannot be any great economy in the vacuum system. In the vacuum system we use steam at a lower temperature. In the ordinary radiator about 60 per cent. of heat goes off by radiation and 40 per cent. by convection of air. When we lower the temperature of the heating surface, the heat given off by radiation to outside walls is reduced. This giving of heat to outside walls is a loss.

Mr. Lewis A. Larsen: I am very much interested in Mr. Hoffman's paper and in the discussion; for this reason, that I have had some experience, not with a vacuum job, but with a job I tried to run at low pressure, and I feel very much as Mr. Kinealy said, that this was a case where the engineer was kept hot, but the occupants were kept warm just the same—it kept me hot about six months. The case I have in mind is the Washburn School, a comparatively new building, built in Duluth three years ago. I designed that plant with the expectation of being able to heat the building with half a pound of steam. It is simply a low-pressure return gravity system—no vacuum. I started in the fall of 1904; maintained the pressure as close as I could to half a pound pressure, and the coal bill was going away up in G. I asked the fireman what the trouble was, and he said, "I have got to keep poking coal to it to keep the building warm. It seems if the pressure gets down at all, the room is cold." We run that through December at as near half a pound of pressure as we could. On the 1st of January we changed our method of procedure and fired up to 8 pounds. We run through the month of January with 33 per cent. less fuel bill than we did through the month of December. Now, I would like to ask some engineer present what is the trouble with the plant? The theory would prove that a half pound of pressure would be more economical than 8 pounds, but in actual practice proved different. I did not attempt to run any test on it. That is actual practice during the two months.

President Snyder: Better combustion, I would suppose.

Mr. Larsen: I had a thermometer in the breeching, and while with low pressure the average temperature of the gases in the breeching was the same, with the 8 pounds it fluctuated; I

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would at some times have a higher temperature and at other times lower; but the average was very nearly the same.

Professor Kinealy: Was your building a new building?

Mr. Larsen: Yes.

Mr. Donnelly: That accounts for it.

Mr. Dougherty: A couple of the gentlemen who have spoken said very positively that there could be no saving in the vacuum system, as far as fuel is concerned, so I understand. I simply want to say this: that six years ago I put in a steam plant in a three-story building, with 2,000 feet of radiation and a 2,600-ft. boiler; mains uncovered, except as the returns came back under the floor; the boiler was on a level; the radiators raised up on the walls. The next year they built an addition, 45 feet wide and 50 feet long, three stories. The boiler would not do the work, and I began using the vacuum system. I put the vacuum system on the job. They said, "We will not buy a new boiler, but if we have to we will buy it after we test it." They are heating that building with the vacuum system attached, with 2,600 feet of radiation, with a 2,600-ft. boiler, with mains, risers and arms, uncovered, and their fuel bill shows not one pound more fuel any one winter in the five years they have used it than when they had 2,000 feet radiation in the boiler, without the vacuum system. In my opinion the vacuum system means a saving in fuel, if that is any criterion to go by. They have shown me their fuel bills for five years, and the result is they are heating the building with that addition to it and that radiation without burning one pound more fuel than the first year, with a smaller building and larger boiler and radiation.

Professor Johnson: Since the middle of the last century it has been well known that there is no such thing as creating or losing energy, that energy in one form when apparently lost always appears in another form with an exact equivalent. The heat units required to heat a room come from some source and some other form of energy, and so far as they are merely heat units it does not make any difference what this source is. It will require the same amount of heat and cost the same from the same source of energy whatever the temperature of the radiating surface may be. It is true we should not stick to theories too closely, but where practice

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bears them out and the theory has been determined as being correct we must stick to it or throw away all modern science.

A professor in a university not far from here two or three years ago weighed certain quantities of ice at certain temperatures very exactly. Under a change of temperature he claims that the ice weighed differently, which would indicate that heat has weight. If true, then the settled theories which I have mentioned above are incorrect, but, as I have heard nothing further from the experiments, I can only infer that he was mistaken. Theories and practice must always agree, providing the theories are correct. Some thirty years ago a controversy came up as to whether an ice boat could go faster than the wind, the claim being made that it could. The matter was presented to Professor Loomis of Yale University and he decided that it was impossible for an ice boat to go faster than the wind which produced its motion. The practical people put an ice boat on the ice which did go faster than the wind. Professor Loomis didn't know that they meant transversely to the wind. If the sail of an ice boat is set on the hypotenuse of a right angle triangle, the shorter leg of the angle being in the direction of the wind and the longer leg at right angle to the direction of the wind, the boat will go an approximate ratio faster than the velocity of the wind as the long leg of the triangle is to the shorter leg. There is no discrepancy between the theory and the practice in this case. Professor Loomis simply did not have in mind the data.

Many years ago I had a class in physics and, in studying the laws of motion, the question came up as to whether a ball once set in motion could move otherwise than in the same straight line, excepting as affected by gravity. I took the stand that it was impossible, the same as Professor Loomis did with reference to the ice boat. The boys said that the ball would curve from a straight line. We set up three stakes in a straight line on the campus and the pitcher, throwing from one side of an end stake, curved the ball around the other side of the middle stake and delivered it on the near side of the farther stake. My theory was apparently wrong. I had not taken into consideration the fact that the ball was revolving on its own axis and the friction of the air on one side, being greater than on the other, curved the ball in the direction of the axis of rotation. So theory and practice really agreed after all.

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Professor Kinealy: Those who have had to do with vacuum systems know there is an economy. Of course there are those who do not have to do with the vacuum system who deny that there is economy, and they are those who denied that the ball curved. We who have to do with the vacuum system know that the balls do curve, and I think that Professor Johnson's illustration is very apt. The economy of the vacuum system is so old a story that it seems to me it is hardly worth talking about. Whenever I hear the economy due to vacuum denied I am reminded of two engineers, both of whom are living to-day; one of whom is on record as saying that it is foolish and childish to think that it would be ever possible to light buildings with electric lamps; "electric lamps are fit only for laboratory experiments." The other is on record, in a report made to a street railway company, as saying, "It is childish and foolish to think it will ever be possible to drive street cars by electricity;" and because of that report the street railway company did not introduce electricity, but put in a cable system, which, five or eight years afterward, they took out and replaced by electricity. There are too many tests, too many experiments, laboratory experiments and tests on actual buildings which show conclusively that there is economy in the use of fuel or in the use of steam when a vacuum system is used, and that the economy is the greater the lower the pressure of the steam in the radiator. There are, at times, cases which come to our notice where more steam will be used at a certain pressure than at a lower pressure or vacuum. Those cases are always explainable, as the case stated by Mr. Larsen, where he heated a new building and he used more fuel.

Professor Bull: I want to disclaim any intention of saying that there is no economy in the vacuum system. I did not state that. I want to emphasize the fact. Still, I would like further to emphasize the fact that I have not yet had any explanation to show where the real economy comes in. That there is economy in actual steam, I do protest against. There may be economy in coal, and with that I agree, but as to steam—no. That a certain amount of steam, at a high pressure, contains more heat units than the other, is perfectly true; in condensing it does not produce as many heat units as low-pressure steam; at the same time, more steam would be circulated; but, taking the whole thing to-

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gether and every circumstance connected with the system, I concede there is economy, but not 20 or 30 per cent.

Mr. Donnelly: I want to say, in line with Mr. Bull, that I do not think Professor Kinealy is correct in quoting anybody that there is no economy in vacuum systems. I think it is a question of where the economy comes from. In regard to economy, I want to say one thing: I saw some years ago a proposition from a certain company or concern guaranteeing economy by the vacuum system, and it specified the way in which the test was to be made—an extraordinary thing. It said, "This plant is to be erected, completed, tested, put in operating, running order and guaranteed to produce economy" of a certain percentage, stating it. I guess the economy was there. There was no reason why it should not be there; but there was nothing said about the temperature of the building. There was economy in the vacuum system, but I suppose the building would have been considerably warmer under one method than another. It was simply a commercial way of making a guaranty and selling an apparatus.

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## CLXXXII.

# FORMULA FOR PIPE SIZES IN HOT WATER HEATING.

BY OLIVER H. SCHLEMMER.

(Member of the Society.)

The subject of pipe sizes in hot-water heating is one that has never been given much attention outside of the discussions along general lines. At present pipe sizes are calculated more or less by rules of thumb, and in some cases by the additional use of tables based on the theoretical velocities, friction not considered. Radiation is figured out quite closely at the present time as a result of the numberless experiments performed; yet, considering the calculation of pipe sizes as a problem in hydraulics, it can be readily seen, that though the radiation may be considered exact for practical purposes, the pipe sizes are not. It may be still further stated that the pipe size calculation, as applied in present practice, is so much in error as to result in some radiators in a system having a much higher and others (in the same system) a much lower average temperature than was actually assumed in figuring the radiation. Still further, in two-pipe systems, the troubles of short circuits and as a consequence no circulation in distant radiators, has been experienced by every heating engineer and contractor. Valves have been inserted in many cases in radiator and riser connections and in the individual parts of vertical risers for the purpose of throttling where necessary to overcome short circuits. Experimenting in trying to overcome these short circuits has been not only a large expense to the contractor, but final dissatisfaction. As a result of this uncertainty in determining pipe sizes, the writer some four years ago decided to go into the problem of pipe sizes and try to obtain a formula which could be applied practically. The results of this work are given in this paper. The formula applies to all systems, it being merely a matter of making up the equations in such a manner as to conform with the principle laid down. Surprising differences in sizes of pipe between the present as used and those worked out by the formula will be noted.

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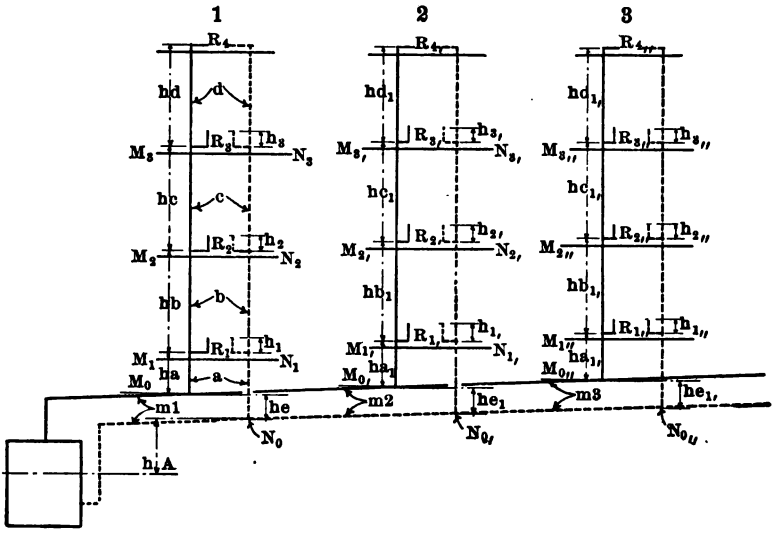
The formula will be first worked out theoretically by means of a two-pipe system, referring to plan I and then a system

PLAN I.




worked out as per plan II. Referring to plan I, the following symbols are used:

$\gamma_1$ = weight of a cubic foot of water at temperature in feed pipe.

$\gamma_2$ = " " " " in return pipe.

$f$ = coefficient of friction for water.

H = heat units passing off per av. sq. ft. of radiation per hour.

H′ = " " " " " " second = H ÷ 3,600.

T = difference in temperature between the feed and the return water or the drop of temperature of water passing through a radiator; *i.e.*, in the system.

R = square feet of radiation.

Q = volume of water in cu. ft. per second flowing through the pipe.

$v$ = velocity of water in feet per second through the pipe.

$\frac{\gamma_2 + \gamma_1}{2} = C_1$

$\gamma_2 - \gamma = C_3$

$\sqrt{\frac{4H'}{\pi C_1 T}} = C_4$

l = length in feet of pipe, including equivalent length for elbows, valves, etc.

d = diameter in feet.

$\frac{4 f C_1}{2 g} = C_2.$

$\sqrt{R} = C.$

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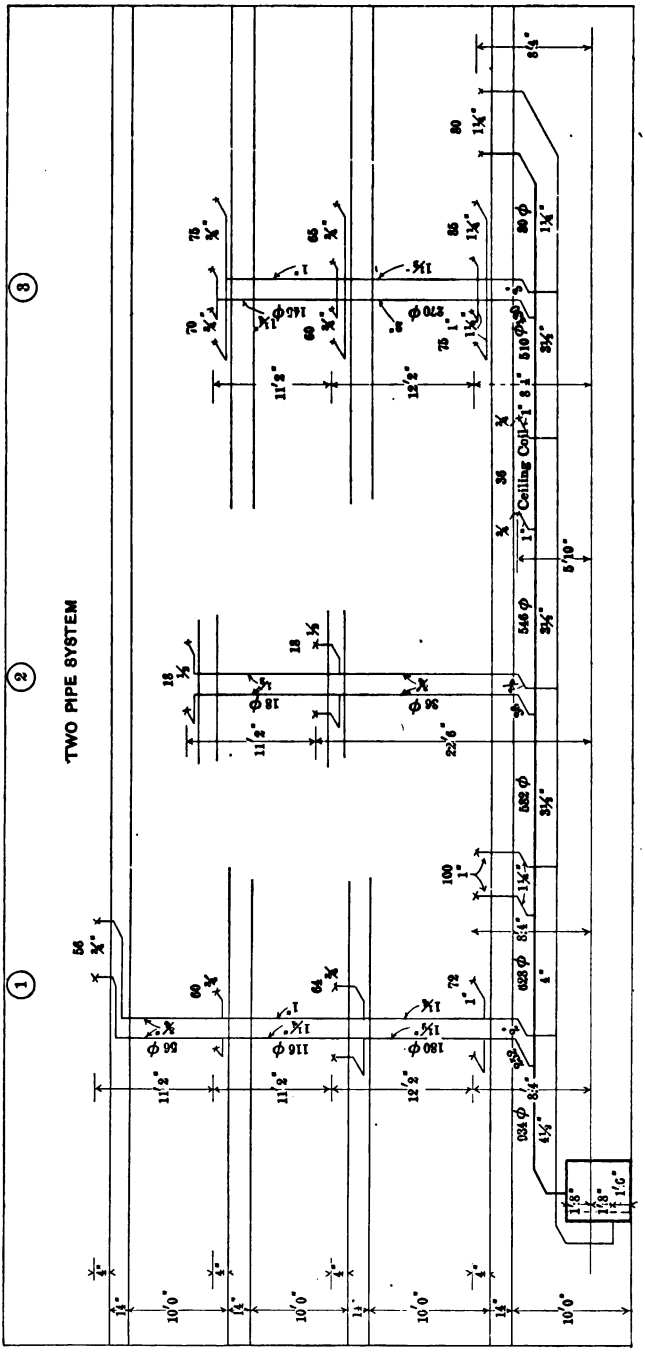
PLAN II.

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The numerals in plan I refer to the individual parts of risers, mains and connections. Then

$$Q_4 = \frac{\pi d_4^2 v_4}{4} = \frac{H' R_4}{C_1 T} \qquad \therefore d_4 = \sqrt{\frac{4H'R_4}{\pi C_1 T v_4}}$$

$$Q_3 = \frac{\pi d_3^2 v_3}{4} = \frac{H' R_3}{C_1 T} \qquad \therefore d_3 = \sqrt{\frac{4H'R_3}{\pi C_1 T v_3}}$$

$$Q_2 = \frac{\pi d_2^2 v_2}{4} = \frac{H' R_2}{C_1 T} \qquad \therefore d_2 = \sqrt{\frac{4H'R_2}{\pi C_1 T v_2}}$$

$$Q_c = \frac{\pi d_c^2 v_c}{4} = \frac{H'(R_4 + R_3)}{C_1 T} \quad \therefore d_c = \sqrt{\frac{4H'(R_4 + R_3)}{\pi C_1 T v_c}} = \frac{C_4 C_c}{v_c^{\frac{1}{4}}}$$

$$Q_x \text{ (in general)} = \frac{\pi d_x^2 v_x}{4} = \frac{H'(R_1 + \ldots R_x)}{C_1 T}$$

$$\therefore d_x = \sqrt{\frac{4H'(R_1 \ldots R_x)}{\pi C_1 T v_x}} = \frac{C_4 C_x}{v_x^{\frac{1}{4}}}$$

It is assumed that the temperature of the water in the feed pipes and that in the return pipes are the same throughout the system. This is not true in practice when the pipes are not covered and when the piping extends a considerable distance from the boiler. Corrections in the radiation can, however, be made for this additional loss in temperature after the formula has been applied and the pipe sizes obtained. It is also assumed that the density of the water throughout is $\frac{\gamma_2 + \gamma_1}{2}$. It is further assumed that the diameters of corresponding feed and return pipes are the same.

The theory is based upon the fact that each return pipe can be considered as a pump with the actuating head equal to the vertical height of the pipe multiplied into the difference in weight of corresponding feed and return water due to the drop in temperature $T$; that this force is transmitted through the system and causes the water to circulate. When the feed and return tappings are at the bottom it is assumed that the vertical height of the radiator has no effect on the circulation in the system but simply locally in the radiator itself.

Consider the part $d$ of riser No. 1 from the third to the fourth floor. The actuating head in this part of the riser is the vertical distance between the centre of the tee connecting to radiator $R_3$ and the centre of tapping in radiator $R_4$ (equal to $h_d$) multiplied into the difference of weight per cubic feet of

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water in the feed and in the return (equal $\gamma_2 - \gamma_1$), resulting in $h_d(\gamma_2 - \gamma_1)$. Again, since the flow of water in the system is to be considered uniform, it follows that the difference in actuating force per unit area between points $M_3$ (the point where the water divides to pass into radiators $R_3$ and $R_4$) and $N_3$ (the point where the water from radiators $R_3$ and $R_4$ join) must equal the friction loss per unit area in the connection to either radiator minus any "actuating head" per unit area in the respective connection. It will be readily seen that this equation is merely a balancing of forces, the flow of water being assumed uniform. Now the force required to overcome friction is represented by the well-known formula $\frac{4f\gamma lv^2}{2gd}$ where $\gamma$ is equal to the density of the water; $l$ = length of pipe in feet; $v$ = velocity in feet per second; $f$ = coefficient of friction; $g = 32.2$; $d$ = diameter of the pipe in feet. In this problem $\gamma = C_1$. From the equation of forces, as above explained, follows the following fundamental principle; *i.e.*, that the friction head minus the "actuating" head in connections common to each other must be equal. Hence we obtain the following equations where $h$ equals the vertical distance between two tees in a riser or between tee and radiator tapping, as the case may be (*i.e.*, in general the vertical height of the actuating head considered).

For riser 1 we have

At points $M_3$, $N_3$, (1) $C_2 \frac{l_3 v_3^2}{d_3} - C_3 h_3 = C_2 \frac{(l_d + l_4) v_d^2}{d_d} - C_3 h_d$

At points $M_2$, $N_2$, (2) $C_2 \frac{l_2 v_2^2}{d_2} - C_3 h_2 = C_2 \frac{l_c v_c^2}{d_c} + C_2 \frac{l_3 v_3^2}{d_3} - C_3 h_c - C_3 h_3$

At points $M_1$, $N_1$, (3) $C_2 \frac{l_1 v_1^2}{d_1} - C_3 h_1 = C_2 \frac{l_2 v_2^2}{d_2} + C_2 \frac{l_b v_b^2}{d_b} - C_3 h_b - C_3 h_2$

At points $M_0$, $N_0$, (4) $C_3 h_A - \gamma_1 h_e \pm C_2 \frac{l_{m1} v_{m1}^2}{d_{m1}} = C_2 \frac{l_a v_a^2}{d_a} + C_2 \frac{l_1 v_1^2}{d_1} - C_3 h_a - \gamma_2 h_e - C_3 h_1$

Transposing in (4) and substituting for $d$ its value in terms of $v$ we have

$$(5)\ \frac{C_3}{C_2}(h_A + h_e + h_a + h_1) = \frac{l_a v_a^{\frac{5}{2}}}{C_4 C_a} + \frac{l_1 v_1^{\frac{5}{2}}}{C_4 C_1} + \frac{l_{m1} v_{m1}^{\frac{5}{2}}}{C_4 C_{m1}}$$

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But $(h_A + h_e + h_a + h_1)$ equals the height from the middle line of the boiler water height to the centre of tapping of radiator $R_1$. Hence calling this $h'_1$.

$$(6)\quad \frac{C_4C_3}{C_2}\, h'_1 = \frac{l_a}{C_a}\, v_a^{\frac{1}{4}} + \frac{l_1}{C_1}\, v_1^{\frac{1}{4}} + \frac{l_{m1}}{C_{m1}} v_{m1}^{\frac{1}{4}}$$

In the same manner we obtain from riser 2

$$(7)\quad \frac{C_4C_3}{C_2}\, h' = \frac{l'_a}{C'_a}\, v'^{\frac{1}{4}}_a + \frac{l'_1}{C_1^1}\, v_1^{\frac{1}{4}} + \frac{l_{m1}}{C_{m1}} v_{m1}^{\frac{1}{4}} + \frac{l_{m2}}{C_{m2}}\, v_{m2}^{\frac{1}{4}}$$

and in the same manner a similar equation for riser 3, etc. It will be seen that there will be as many equations as are risers (connections off mains). But there are more variables (velocities) than are required to solve the problem which means that the work could be laid out in an almost infinite number of ways. It is uniformity as far as possible in the velocities that we desire to obtain as producing the least eddy friction as a result of large changes in velocities at reducing tees. Therefore, since there are no other conditions to be observed, we will make the velocity in part *a* of riser 1 equal to that in connection $R_1$ and likewise in riser 2, etc., as also the velocities in different parts of the mains (1), (2), etc. equal throughout. This will make equations (6) and (7) as follows:

$$(8)\quad \frac{C_4C_3}{C_2}\, h'_1 = \left(\frac{l_a}{C_a} + \frac{l_1}{C_1}\right) v_1^{\frac{1}{4}} + \frac{l_{m1}}{C_{m1}}\, v_{m1}^{\frac{1}{4}}$$

$$(9)\quad \frac{C_4C_3}{C_2}\, h' = \left(\frac{l'_a}{C'_a} + \frac{l'_1}{C'_1}\right) v_1^{\frac{1}{4}} + \left(\frac{l_{m1}}{C_{m1}} + \frac{l_{m2}}{C_{m2}}\right) v_{m1}^{\frac{1}{4}}$$

and in general

$$(10)\quad \frac{C_4C_3}{C_2}\, h = \Sigma \left(\frac{l_r}{C_r}\right) v_r^{\frac{1}{4}} + \Sigma \left(\frac{l_M}{C_M}\right) v_M^{\frac{1}{4}}$$

Where *r* refers to riser and *M* to main, $\Sigma$ = summation. Equation (10) is the equation by means of which any system of hot-water heating pipe sizes can be solved. There will be as many similar equations as there are connections off mains. The value of $\frac{C_3C_4}{C_2}$ depends, as seen before, on T, difference of temperature between feed and return water and also on H, the heat units given off per square foot per hour. From the series of equations similar to the above general equation it will be seen that there is one more variable than necessary to solve

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the equations. As a consequence, any velocity for the mains could be assumed such as would positively satisfy all equations. It is desirable to obtain the largest possible velocity so as to obtain small diameters of piping. This can be obtained by inspection of the various equations similar to (10), assuming the riser velocities equal to the main velocity and such an equation found as will give the proper velocity and still maintain the equations positive. Having found $v_m^{\frac{1}{5}}$ in this way it is an easy matter by means of the slide rule to find $v_r^{\frac{1}{5}}$ and then from fifth root tables $v_r^{\frac{1}{5}}$. $d_r = \frac{C_4 C_r}{v_r^{\frac{1}{5}}}$ as seen before. From this, knowing $v_r^{\frac{1}{5}}$, $d_r$ can be found. In like manner the diameters of the mains can be fixed. To obtain the diameters for parts *b*, *c* and *d*, also for the connections in $R_2$ $R_3$ and $R_4$ in riser I, after having solved the main velocities and velocities in parts *a*, of all riser connections, equations (1), (2) and (3) are used, simply rearranging them as in solving equation (10) with the assumption which can be made that velocity in part *b* equals velocity in radiator connection $R_2$, that in part *c* equals that in radiator connection $R_3$, and that in part *d* equals that in $R_3$. It is to be noted, however, that velocities *a*, *b*, *c* and *d* will all be different from one another. This, then, gives for equation

(3) (11) $$\left(\frac{l_2}{C_2} + \frac{l_b}{C_b}\right) v_2^{\frac{1}{5}} = \left(\frac{l_1}{C_1}\right) v_1^{\frac{1}{5}} + \frac{C_4 C_3}{C_2} (h_b + h_2 - h_1)$$

(2) (12) $$\left(\frac{l_3}{C_3} + \frac{l_c}{C_c}\right) v_3^{\frac{1}{5}} = \left(\frac{l_2}{C_2}\right) v_2^{\frac{1}{5}} + \frac{C_4 C_3}{C_2} (h_c + h_3 - h_2)$$

(1) (13) $$\left(\frac{l_d + l_4}{C_4}\right) v_4^{\frac{1}{5}} = \left(\frac{l_3}{C_3}\right) v_3^{\frac{1}{5}} + \frac{C_4 C_3}{C_2} (h_d - h_3)$$

Taking equation (11) it is seen that $v_1^{\frac{1}{5}}$ has been solved by equation (10). There being only one unknown quantity $v_2^{\frac{1}{5}}$, this can be easily solved and then equations (12) and (13) and then *d* as in solving (10). Equations (11), (12) and (13) show very nicely, as did equation (10), that the friction losses must balance the actuating heads due to a difference of temperature T in the system. By constant use of this formula it will be found that different assumptions as to which parts shall have equal velocities can be made. The writer has sometimes assumed the velocities in the entire individual riser as equal making the velocities in the connections different. This assumption, how-

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ever, may give negative results for some of the lower connections. It will be seen that by the method shown in equations (11), (12) and (13) the right-hand side of the equations will always be positive. This method is therefore preferred.

The writer uses equation (10) in the form

$$(14)\quad \Sigma\left(\frac{l_r}{C_r}\right) v_r^{\frac{5}{2}} = \frac{C'_4 C_3}{C_2}\sqrt{H}h - \Sigma\left(\frac{l_M}{C_M}\right) v_M^{\frac{5}{2}}$$

$$\text{where } C'_4 = \sqrt{\frac{4}{\pi C_1 T \times 3{,}600}} = \frac{C_4}{\sqrt{H}}$$

This formula will be applied to a two-pipe system. Before doing this, however, explanation of the various coefficients will be made.

It is a difficult matter to determine just what value of $f$, the coefficient of friction, to use, considering the couplings and tees which make up a part of the piping. As the writer has found that the velocity in the mains averages about 0.25 feet per second and in the risers and connections from 0.25 to 0.64 feet per second, he decided to take $f = 0.007$ for a velocity of 0.3 feet per second for an 8-inch pipe as per table by Fanning (Darcy's Formula) and make the corrections in $l$ for larger or smaller sized pipe as per this table before applying the $l$ to the formula. The proportions of $l$ to be added or subtracted are given in table A. Referring to general equation (11) it will be seen that any error in selecting $H$ or $f$ will not affect the system as far as proper proportion is concerned. The velocities are all affected, but in a proportionate manner. Table B gives the values of $C_3$, $C'_4$, and $\frac{C'_4 C_3}{C_2}$ for different differences of temperature $T$.

The friction of elbows is found by use of Prof. L. E. Bellinger's formula (See Church's Mechanics, p. 729). Allowance, however, is made by the writer for different diameters on account of the low velocities as per table A. Thus each elbow is equal in equivalent length of pipe in feet to twice the diameter in inches. For friction loss at exit of feed water from boiler as also return water out of radiator a length equivalent to that of 1½ elbows should be used. For connections off of mains when the main does not reduce at the connection, a length equivalent to 3 elbows is assumed by the writer as friction of entrance into feed connections and resistance in return con-

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nection. When a reduction is made 2 elbows are allowed instead of 3. In the case of risers, on account of the small size pipe used, an equivalent of 4 elbows where there is no reduction and 3 elbows where there is a reduction should be allowed. When deflecting fittings are used in the risers 1½ elbows should be allowed and ½ elbow in the riser above deflecting fitting. For radiator valves an equivalent of 1½ elbows should be allowed. There is no information available as to the above frictional resistances of connections and until such can be obtained the above values can be safely used. It is found, however, that in ½″ connections it is better to use a ¾″ connection and then reduce to ½″.

The solution of the two-pipe system, plan II, is shown as follows. It is necessary to assume the sizes throughout. This can very easily be done approximately after working out a number of plans. An assumption of one size larger or smaller or even two sizes than the true value does not appreciably affect the results, provided, of course, there are not too many discrepancies. If there are any large discrepancies corrections must be made. The assumption of the diameters is merely made to obtain a value for $l$, the length, and has nothing to do with the diameters resulting from the formula. It will be found that the variation in $l$, due to an error in assumption of the diameters, will be very small—less than 10 per cent., and have no appreciable effect on the results. (The practical problem worked out in this paper has been worked out, assuming almost all the diameters exact so as to allow of inspection of the very small difference which would result had the diameters been assumed too large or too small.) Plan I shows the radiation and heights from centre of boiler proper to the different radiators.

Sheets 1 and 2 show how the values for $\frac{1}{C}$ for the various parts of mains and risers are determined. Following a line across the sheet, it will be seen that first comes radiation on part under consideration, then assumed size, then $l$ (including elbow equivalent), then $\frac{1}{C}$, then $\frac{12\,C'_4\sqrt{H}}{v^{\frac{1}{4}}}$ as determined by the equations, then the value of $\frac{12\,C'_4 C\sqrt{H}}{v^{\frac{1}{4}}}$ (the diameter), then the "made"

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diameter. It is impossible to obtain pipe in the market which will give exact diameters, as figured above. Consequently good judgment must determine whether the next size shall be used or whether a part shall be made one size smaller and a part one size larger. This proportion could be exactly determined, but the result is not worth the trouble. Sheet 3 shows the equations worked out similar to general equation (14). It is seen that the 36 square foot radiator determines the size of the main. From this equation find $v_M^{\frac{5}{2}}$, then multiply this into the $\Sigma\frac{l_M}{C_M}$ on the right side of the equations, place result immediately under the first member of the right side of the equations, subtract and place above the member of left side of equation. Divide this and we have $v_r^{\frac{5}{2}}$ from which we obtain $v_r^{\frac{1}{2}}$ and then the corresponding $d_r$.

All systems can be worked out in this manner. The length of this paper, however, will not permit of working out these systems or going into discussion of the drop in temperature in mains, due to radiation as affecting the radiation and circulation, the assumption of $\gamma_1$ and $\gamma_2$ at their corresponding temperatures as affecting the various coefficients and the many other conditions which arise in a system of hot-water heating. Suffice it to say, however, that this method of figuring pipe sizes has been used by the writer in all of his installations. Many new problems are repeatedly coming up and from the experience of their installations new information is to be gained which may add in time to the improvement of this formula.

TABLE A.

| Dia. | Add. |
|---|---|
| ½ | 1 1 |
| ¾ | ¼ " |
| 1 | ⅛ " |
| 1¼ | 1/16 " |
| 1½ | 1/32 " |
| 2 | 1/64 " |
| 2½ | 1/128 " |
| 3 | 1/256 " |
| 3½ | 1/512 " |
| 4 | 1/1024 " |
| 4½ | 1/2048 " |
| 5 | 1/4096 " |
| 6 | 1/8192 " |
| 7 | 1/16384 " |
| 8 | 0 " |
| 9 | −1/16384 " |
| 10 | −1/32768 " |

TABLE B.

| Difference in Temp. T | $\sqrt{\frac{4}{\pi C_1 T 3600 C'_4}}$ | $\frac{\gamma_2 - \gamma_1}{C_3}$ | $\frac{C'_4 C_2}{C_2}$ |
|---|---|---|---|
| 5 | .0011 | .11 | .0045 |
| 10 | .00076 | .21 | .0060 |
| 15 | .00062 | .32 | .0075 |
| 20 | .00054 | .42 | .0085 |
| 25 | .00048 | .52 | .0094 |
| 30 | .00044 | .62 | .0103 |
| 35 | .00041 | .71 | .0110 |
| 40 | .00038 | .81 | .0120 |

$C_1 = 61.00$
$\gamma_1 = 60.66$ (at 175°)
$\gamma_2$ varies from this down.
$f = .007$

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## TWO PIPE SYSTEM—PLAN II.

### MAINS.

| RADIATION. | SIZE ASSUMED. | l | $\frac{l}{c}$ | $\frac{12\ C'_4\ \sqrt[4]{H}}{v^{\frac{1}{4}}}$ | d | MADE. |
|---|---|---|---|---|---|---|
| *Sq. Ft.* | *Inches.* | | | | | *Inches.* |
| 934 | 4½ | $l = 42$; $6\frac{1}{2} - e = 59$; $101 + \frac{1}{16} = 107$ | $\frac{107}{\sqrt{934}} = \frac{107}{30.54} = 3.50$ | 0.152 | 4.65 | 4½ |
| 682 | 4 | $l = 32$; $0 - e = 0$; $32 + \frac{1}{16} = 35$ | $\frac{35}{\sqrt{682}} = \frac{35}{26.14} = 1.34$ | 0.152 | 3.96 | 4 |
| 582 | 4 | $l = 29$; $0 - e = 0$; $29 + \frac{1}{16} = 31$ | $\frac{31}{\sqrt{582}} = \frac{31}{24.12} = 1.29$ | 0.152 | 3.67 | 3½ |
| 546 | 3½ | $l = 26$; $0 - e = 0$; $26 + \frac{1}{16} = 31$ | $\frac{31}{\sqrt{546}} = \frac{31}{23.38} = 1.33$ | 0.152 | 3.55 | 3½ |
| 510 | 3½ | $l = 14$; $0 - e = 0$; $14 + \frac{1}{16} = 16$ | $\frac{16}{\sqrt{510}} = \frac{16}{22.59} = 0.71$ | 0.152 | 3.44 | 3½ |

### RISER I—VERTICAL PARTS.

| | | | | | | |
|---|---|---|---|---|---|---|
| 252 | 2 | $l = 12$; $6 - e = 24$; $36 + \frac{1}{2} = 43$ | $\frac{43}{\sqrt{252}} = \frac{43}{15.85} = 2.71$; $3.78$; $6.49$ | 0.126 | 2.02 | 2 |
| 180 | 1½ | $l = 22$; $\frac{1}{2} - e = 1\frac{1}{2}$; $23\frac{1}{2} + \frac{1}{2} = 33$ | $\frac{33}{\sqrt{180}} = \frac{33}{13.40} = 2.46$; $4.25$; $6.71$ | 0.109 | 1.46 | Feed = 1½ Ret. = 1½ |
| 116 | 1½ | $l = 24$; $\frac{1}{2} - e = 1\frac{1}{2}$; $25\frac{1}{2} + \frac{1}{2} = 38$ | $\frac{38}{\sqrt{116}} = \frac{38}{10.78} = 3.53$; $5.55$; $9.08$ | 0.109 | 1.18 | Feed = 1¼ Ret. = 1 |

### RISER I—CONNECTIONS.

| | | | | | | |
|---|---|---|---|---|---|---|
| 72 | 1 | $l = 4$; $7\frac{1}{2} - e = 15$; $19 + \frac{1}{2} = 22$ | $\frac{22}{\sqrt{72}} = \frac{22}{8.48} = 3.78$ | 0.126 | 1.06 | 1 |
| 64 | ¾ | $l = 3\frac{1}{2}$; $9\frac{1}{2} - e = 15\frac{1}{2}$; $19 + \frac{1}{2} = 34$ | $\frac{34}{\sqrt{64}} = \frac{34}{8.00} = 4.25$ | 0.109 | 0.87 | ¾ |
| 60 | ¾ | $l = 14$; $7\frac{1}{2} - e = 11$; $25 + \frac{1}{2} = 43$ | $\frac{43}{\sqrt{60}} = \frac{43}{7.75} = 5.55$ | 0.109 | 0.846 | ¾ |
| 56 | ¾ | $l = 37$; $10\frac{1}{2} - e = 16$; $53 + \frac{1}{2} = 92$ | $\frac{92}{\sqrt{56}} = \frac{92}{7.48} = 12.30$ | 0.113 | 0.844 | ¾ |

### RISER II—VERTICAL PARTS.

| | | | | | | |
|---|---|---|---|---|---|---|
| 36 | ¾ | $l = 34$; $7 - e = 10$; $44 + \frac{1}{2} = 77$ | $\frac{77}{\sqrt{36}} = \frac{77}{6} = 12.83$; $6.37$; $17.20$ | 0.126 | 0.755 | ¾ |

### RISER II—CONNECTIONS.

| | | | | | | |
|---|---|---|---|---|---|---|
| 18 | ½ | $l = 4$; $9\frac{1}{2} - e = 9\frac{1}{2}$; $18\frac{1}{2} + 1 = 27$ | $\frac{27}{\sqrt{18}} = \frac{27}{4.24} = 6.37$ | 0.127 | 0.542 | ½ |
| 18 | ½ | $l = 28$; $8\frac{1}{2} - e = 8\frac{1}{2}$; $36\frac{1}{2} + 1 = 72$ | $\frac{72}{\sqrt{18}} = \frac{72}{4.24} = 25.70$ | 0.126 | 0.534 | ½ |

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## TWO PIPE SYSTEM—PLAN II. *Continued.*

### RISER III—VERTICAL PARTS.

| RADIATION. | SIZE ASSUMED. | l | $\frac{l}{c}$ | $\frac{12\ C'_4\ \sqrt{H}}{v^{\frac{1}{3}}}$ | d | MADE. |
|---|---|---|---|---|---|---|
| *Sq. Ft.* | *Inches.* | | | | | *Inches.* |
| 430 | 3 | $l = 14$, $6 - e = 36$, $\overline{50} + \frac{1}{2} = 56$ | $\frac{56}{\sqrt{430}} = \frac{56}{20.71} = 2.70$, $4.88$, $7.58$ | 0.142 | 2.94 | 3 |
| 270 | 2 | $l = 24$, $0 - e = 0$, $\overline{24} + \frac{1}{2} = 29$ | $\frac{29}{\sqrt{270}} = \frac{29}{16.41} = 1.77$, $4.34$, $6.11$ | 0.110 | 1.81 | Feed = 2, Ret. = 1½ |
| 145 | 1½ | $l = 22$, $0 - e = 0$, $\overline{22} + \frac{1}{2} = 33$ | $\frac{33}{\sqrt{145}} = \frac{33}{12.04} = 2.74$, $4.15$, $6.89$ | 0.103 | 1.235 | Feed = 1½, Ret. = 1 |

### RISER III—CONNECTIONS.

| | | | | | | |
|---|---|---|---|---|---|---|
| 75 | 1½ | $l = 6$, $9 - e = 23$, $\overline{29} + \frac{1}{2} = 43$ | $\frac{43}{\sqrt{75}} = \frac{43}{8.66} = 4.97$ | 0.143 | 1.94 | Out. = 1½, Conn. = 1 |
| 85 | 1½ | $l = 7$, $9 - e = 23$, $\overline{30} + \frac{1}{2} = 45$ | $\frac{45}{\sqrt{85}} = \frac{45}{9.22} = 4.88$ | 0.142 | 1.81 | 1½ |
| 60 | ¾ | $l = 6$, $9 - e = 14$, $\overline{20} + \frac{1}{2} = 35$ | $\frac{35}{\sqrt{60}} = \frac{35}{7.75} = 4.52$ | 1.109 | 0.84 | ¾ |
| 65 | ¾ | $l = 6$, $9 - e = 14$, $\overline{20} + \frac{1}{2} = 35$ | $\frac{35}{\sqrt{65}} = \frac{35}{8.06} = 4.34$ | 0.108 | 0.87 | ¾ |
| 70 | ¾ | $l = 8$, $8 - e = 12$, $\overline{20} + \frac{1}{2} = 35$ | $\frac{35}{\sqrt{70}} = \frac{35}{8.36} = 4.18$ | 0.103 | 0.86 | ¾ |
| 75 | | $l = 9$, $8 - e = 12$, $\overline{21} + \frac{1}{2} = 36$ | $\frac{36}{\sqrt{75}} = \frac{36}{8.66} = 4.15$ | 0.103 | 0.887 | ¾ |

### FIRST FLOOR AND BASEMENT CONNECTIONS.

| | | | | | | |
|---|---|---|---|---|---|---|
| 100 | 1½ | $l = 10$, $10 - e = 25$, $\overline{35} + \frac{1}{2} = 52$ | $\frac{52}{\sqrt{100}} = \frac{52}{10} = 5.2$ | 0.125 | 1.25 | Over = 1½, Up = 1 |
| 36 | ¾ | $l = 6$, $9 - e = 14$, $\overline{20} + \frac{3}{4} = 35$ | $\frac{35}{\sqrt{36}} = \frac{35}{6} = 5.84$ | 0.152 | 0.913 | Over = 1, Conn. = ¾ |
| 80 | 1½ | $l = 26$, $10 - e = 25$, $\overline{51} + \frac{1}{2} = 76$ | $\frac{76}{\sqrt{80}} = \frac{76}{8.95} = 8.50$ | 0.146 | 1.30 | 1½ |

## EQUATIONS.

Average Temperature in Radiator = 180°

$T = 20°$ $\quad \frac{C'_4\ C_2}{C_2} = 0.0085$ $\quad C'_4 = 0.00054$ $\quad H = 165,\ \sqrt{H} = 12.8$

$C'_4\ \sqrt{H} \times 12 = 0.083$

$0.0085 \times 12.8 \times 5.83 = 0.635$
$0.0085 \times 12.8 \times 8.32 = 0.905$
$0.0085 \times 12.8 \times 11.16 = 1.215$
$0.0085 \times 12.8 \times 12.16 = 1.322$
$0.0085 \times 12.8 \times 22.50 = 2.045$

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## MAIN EQUATIONS.

| | | | $v^{\frac{5}{2}}$ | $v^{\frac{1}{2}}$ |
|---|---|---|---|---|
| I. | 72 | $\frac{0.737}{6.47} = \frac{0.905}{0.168} - \frac{3.50}{1.34}$ | .114 | 0.65 |
| | 100 | $\frac{0.674}{5.2} = \frac{0.905}{0.231} - \frac{4.84}{1.29}$ | 0.130 | 0.665 |
| II. | 18 | $\frac{2.16}{17.20} = \frac{2.45}{0.29} - \frac{6.13}{1.33}$ | 0.125 | 0.66 |
| | 36 | $\frac{0.279}{5.84} = \frac{0.635}{0.356} - \frac{7.46}{0.71}$ * | 0.048 | 0.545 |
| III. | 85 | $\frac{0.515}{7.58} = \frac{0.905}{0.390} - 8.17$ | 0.068 | 0.585 |
| | 80 | $\frac{0.515}{8.50} = \frac{0.905}{0.390} - 8.17$ | 0.061 | 0.57 |
| | | $\frac{0.635}{13.30} = 0.048$ | 0.048 | 0.545 |
| I. | 64 | $\frac{1.751}{6.71} = \frac{1.322}{0.429} + 3.78 \times 0.114$ | 0.261 | 0.765 |
| I. | 60 | $\frac{2.325}{9.08} = \frac{1.215}{1.110} + 4.25 \times 0.261$ | 0.256 | 0.76 |
| I. | 56 | $\frac{2.635}{12.30} = \frac{1.215}{1.42} + 5.55 \times 0.256$ | 0.214 | 0.735 |
| II. | 18 | $\frac{2.015}{17.00} = \frac{1.215}{0.800} + 6.37 \times 0.125$ | 0.118 | 0.65 |
| III. | 75 | $\frac{0.382}{4.97} = 4.88 \times 0.068$ | 0.067 | 0.58 |
| III. | 65 | $\frac{1.654}{6.11} = \frac{1.322}{0.332} + 4.88 \times 0.068$ | 0.271 | 0.77 |
| III. | 60 | $\frac{1.175}{4.52} = 4.34 \times 0.271$ | 0.260 | 0.765 |
| III. | 75 | $\frac{2.390}{6.89} = \frac{1.215}{1.175} + 4.84 \times 0.271$ | 0.347 | 0.81 |
| III. | 70 | $\frac{1.44}{4.18} = 4.75 \times 0.347$ | 0.344 | 0.81 |

## DISCUSSION.

Mr. Schlemmer: I have found in my experience that we have been involved a good deal in short circuits; it has been a large expense to our company, and I know every heating contractor has been through the same trouble, so I decided to work out a formula. It is complicated, yet it is clear when you have studied it. The formula as first evolved was not in the same form as the present one, in that the coefficients of friction were different.

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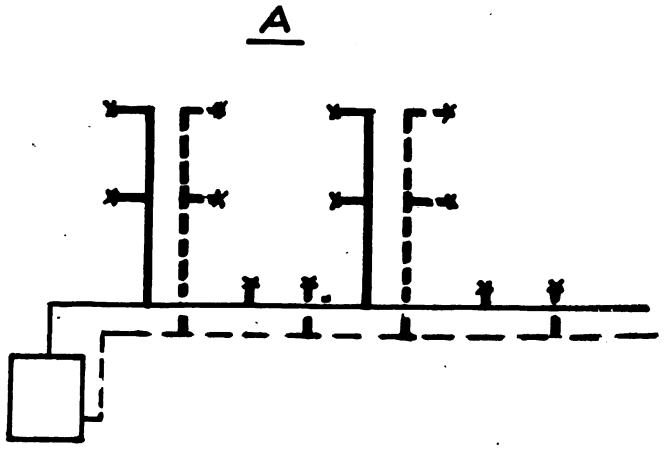
Plan II has been worked out by the formula and shows the actual scientific pipe sizes which should be employed, with a difference in temperature between the feed and the return of 20 degrees.

The present practice of pipe sizes for a 75 square foot radiator on the third floor is to put in 1¼-inch; plan II shows the size ¾-inch. Take the 100 square foot radiator on first floor, which in practice calls for 1½-inch pipe, I use 1¼-inch over and 1 inch up. Distribution of friction throughout the system determines the sizes. They may work out differently for the same size radiators. I have found in our present practice that our mains are entirely too small and our risers too large. I have gotten this formula down now to such a point that I can put in connections that I do not believe the ordinary fitter would attempt. As to the coefficient of friction, all of our experiments have been with very high velocities. The velocity of the water through a main, be it two-pipe system, one-pipe or the overhead system is about 15 feet a minute.

Mr. Jas. Mackay: You refer especially to hot water?

Mr. Schlemmer: Yes. There are no experiments on friction I know of, except Darcy's, which were performed with very low velocities, and those are the coefficients I have used. We need experiments on the coefficients of friction with low velocity for various fittings, such as valves, elbows, etc.

Mr. Widdicombe: Is it possible to give a less drop in the




MR. SCHLEMMER'S SKETCH A.

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risers and more drop in the main and change the form of the equation?

Mr. Schlemmer: Yes.

Mr. Widdicombe: Would not that change the present practice you speak of as being incorrect and bring the size of the risers up?

Mr. Schlemmer: No. You will find, if you assume a larger velocity in the mains, that some main equations will become negative, which means that there is not enough head to circulate the water at the required velocity through certain radiators, take the 36-foot radiator, the basement ceiling radiator in plan II for example.

Mr. Widdicombe: I was trying to reconcile you with current practice in reference to sizes of pipes, that is a more even velocity and drop throughout.

Mr. Schlemmer: I will illustrate what the practice now is. Refer to sketch A; the thickness of the heavy lines represent the proportionate diameters of the pipes. In other words, consider the risers and connections as being large cylinders attached to small horizontal pipes (mains). You will find that you use different combinations of this principle. The friction in risers is almost zero, while that in the mains is large. The results are short circuits and merely local circulation in the risers themselves.

Mr. Widdicombe: Suppose you had a sort of thermal-syphon effect in the drop, like you have in the drop leg system, the idea being to carry the water to a higher point and gain the velocity, as you would effect if you ran a stand pipe up a building in an overhead job—i. e., you would have smaller side pipes—and if you had a long horizontal run it would help that run.

Mr. Jas. Mackay: A vertical supply to a horizontal overhead system.

Mr. Widdicombe: Would you not get a higher velocity in the horizontal run on account of going up and dropping down?

Mr. Schlemmer: If the drop leg is less in temperature, of course.

Mr. Widdicombe: It naturally would, because the temperature drop is part of the game, and the steam bubbles in the riser assist it in an overhead system.

Mr. Schlemmer: I do not exactly understand your explanation.

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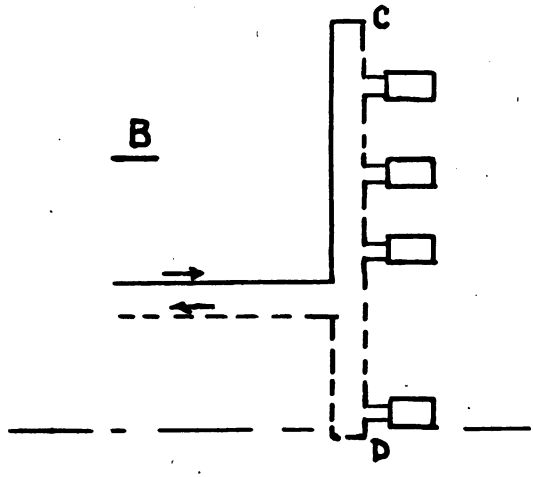
Mr. Widdicombe: The accompanying illustration, sketch B, shows what I mean.




MR. WIDDICOMBE'S SKETCH B.

Mr. Schlemmer: I am figuring this on a 20 degree drop in temperature between point C and point D on the overhead principle.

Mr. Widdicombe: Yes, but you have the water in the drop pipe coming down at quite a velocity. Cannot you get over this velocity?

Mr. Schlemmer: You mean on account of the drop leg?

Mr. Widdicombe: I mean from C to D.

Mr. Schlemmer: It all depends on the way you figure. If you figure a 20 degree drop between C and D, I would say no.

Prof. Kinealy: Suppose you figure 20 degrees in each radiator in the drawing.

Mr. Schlemmer: Yes.

Prof. Kinealy: For two floors you would have a difference of 40 degrees, and for three floors you would have a difference of 60 degrees.

Mr. Widdicombe: Will your theory work out if you run a riser up to the high point of a building and drop down, say under the first floor on the ceiling of the basement, and hook up radiators around the first floor, rising up through the floor to them?

Mr. Schlemmer: It is a matter of working it out. The system may or may not work. The theory will work out. You

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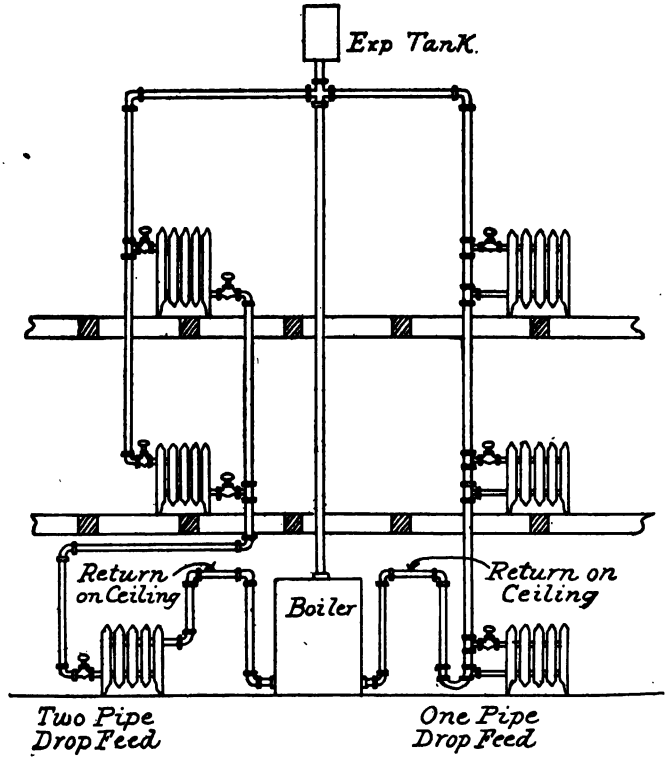
would find that if you dropped your return below the return main and then up to it, you may be able to get a circulation through such low radiators.

Mr. Widdicombe: We know you can get circulation through it.

Mr. Schlemmer: Yes, but you must figure scientifically. You must work it out by the formula. If you get a negative result it will not work.

Mr. Widdicombe: Suppose you put a radiator on the basement floor below the basement return, as in the accompanying sketch C?




MR. WIDDICOMBE'S SKETCH C.

Mr. Schlemmer: With a two-pipe system?

Mr. Widdicombe: Yes; feeding it from the return riser above.

Mr. Schlemmer: It is possible. It all depends on how the friction throughout the other risers is distributed.

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Mr. Widdicombe: Does the theory hold?

Mr. Schlemmer: Yes.

Prof. Kinealy: I want to make a criticism of Mr. Schlemmer's formula. As I understand, Mr. Schlemmer puts his velocity in feet per second, and yet you hear us speak of velocity in feet per minute. D is the diameter of the pipe in feet. No one ever uses such a unit. I should like those formulas to be given to us in the units we ordinarily use. I use a formula that is very much simpler than that. While it is not exact, it is sufficiently accurate for all practical purposes. The friction head is given by the following formula:

$$f = \frac{0.3l}{d}\left(\frac{v}{500}\right)^2, \text{ in which}$$

$f$ is the head in feet to overcome friction; $l$ length of pipe in feet, $d$ is the diameter of the pipe in inches, and $v$ is the velocity of the water in the pipe in feet per minute.

That formula assumes, of course, that the coefficient of friction is practically constant for all velocities met with in our work. It is seldom that the velocity in hot water heating exceeds half a foot a second, or 30 feet a minute. I think that the allowance for elbow than Mr. Schlemmer makes is rather small. He says that an elbow is equivalent to a pipe whose length is two times the diameter of the elbow, the diameter being given in inches and the length being given in feet; that is, the friction of an inch elbow would be equivalent to the friction of two feet of inch pipe. It seems to me that is very small. That might be so if the diameter, or rather the radius of the elbow be about 4 inches, and that is a pretty long sweep elbow. For an ordinary square elbow I use five times the diameter of the pipe, but with an ordinary elbow such as we get on the market I use three times the diameter of the pipe. It is almost impossible to know what length of pipe to add for valves. In the case of a T, I assume that it is a square elbow.

Mr. Schlemmer: That is too much, in my opinion. The reason I did not put the formula in feet is that that has nothing to do with my results. In the problem under "Main Equations" I work out the main equation and get the velocity in feet per second. From that it is merely a question of getting the diameter.

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I simply take the diameter coefficient under "Equations"—$C'_4$—and multiply that by 12 to change that coefficient into inches. It does not finally enter into the formula which is used to obtain sizes.

Prof. Kinealy: It is not that. It is that if we are in the habit of thinking in certain units, when the units are different from those we are accustomed to use, we have to translate mentally before we can get the drift of the formula.

Mr. Schlemmer: I take this from hydraulic engineering. Those equations are always figured out in feet per second as units. Different organizations are changing those things. In the heating line, I suppose, the diameter is taken in inches. I have installed according to this formula between 50 and 65 jobs. I have here a set of plans of an actual job in operation for your inspection. I could not make thorough tests because I did not have time. You cannot be sure of the exact result of temperature drop on account of the variation in effect of radiation under different conditions. I was compelled to put the thermometer up against the pipe with a piece of asbestos and stove cement in testing riser and radiator connections. In testing mains, thermometer cups were tapped in the mains.

Prof. Kinealy: Do you find the drop as low as 20 degrees?

Mr. Schlemmer: Lower than that.

Prof. Kinealy: You mean the difference is lower than 20 degrees.

Mr. Schlemmer: Yes. On all my jobs I put a thermometer cup in the feed and in the return. I test them 20 to 30 degrees outside temperature. In Cincinnati there are but two or three days of zero weather, and I generally have not the time on such days for testing, but there is a larger loss between the temperature of feed and the return mains, due to the radiation in the cellar, and that loss is considerable. What it will be I am not prepared to state until I make more thorough tests. As far as short circuits are concerned, outside of tests with the thermometer, you can put your hand on any radiator and you cannot notice the difference. I think I am pretty close to the truth, because if I make the diameter of any of these pipes one size too large I can notice the difference in the surrounding radiators. That comes about because the friction varies inversely in this formula, as the fifth power of the diameter.

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Professor Allen: We have been making some experiments at the University of Michigan to determine the velocity of water with a natural circulation, due to the difference in temperature between hot and cold leg of the system, and have decided that this can be done without introducing friction. Up to the present time we have been endeavoring to determine the velocity of flow produced by different temperatures in hot and cold weather. These results, however, have been difficult to interpret, as we do not obtain the velocity of flow that is anticipated. I wish to ask Mr. Schlemmer now to determine his coefficient of friction. I have worked on this two or three years and am still not satisfied with my own results.

Mr. Schlemmer: When I first used this formula I used .007, which was a coefficient everyone used for water work, and I found on the small pipe, ¾-inch and ½-inch pipe, there was a difference in temperature that I could not notice on the 1½-inch and 2-inch pipe. For instance, in a particular job, where a 1½-inch riser was very close to a ¾-inch riser and figured in the same way, there was a noticeable difference in temperature between corresponding pipes. That led me to believe that the diameter had something important to do with the friction coefficient. That is why I used Darcy's formula, and since then noticed very little variation.

Professor Allen: So far we have been experimenting with 1½-inch pipe with different velocity of flow and different temperatures in hot and cold leg. Figuring theoretical flow from the difference in weight between the hot and cold leg shows, speaking from memory, that the actual velocity is from 50 per cent. to 70 per cent. of the theoretical velocity. These experiments, however, have not been completed and are still in progress.

Mr. Schlemmer: I have also found that the entrance coefficient on ½-inch connections is large. I usually use ¾-inch openings and reduce to ½ inch in the connection.

Professor Kinealy: Do you mean a commercial half-inch pipe or a half-inch pipe? What is a commercial half-inch pipe in your formulas?

Mr. Schlemmer: About 0.62 in diameter.

Professor Kinealy: You reduce the entrance coefficient.

Mr. Schlemmer: Yes, which indicates that the entrance coefficient, as I have it, is a little incorrect.

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Professor Kinealy: I see. Five times the diameter of the pipe.

Mr. Schlemmer: You will notice there is an inch and a quarter connection taken off at the end of the mains in plan II, where a high riser is taken off. I find there is a difference in temperature in that connection from that figured when there is a large difference in diameter of pipe between the two connections. That could be expected, but I think it is due more to the centrifugal force of the water coming back in the return rather than to the sudden reduction in sizes at that point.

Professor Kinealy: You mean when the riser is working, as it ought, to its full capacity, the water will not go through the horizontal.

Mr. Schlemmer: It will go through. You cannot, however, notice the comparative difference of temperature by the hand. It is very slight, five or eight degrees difference. What I do now, instead of running a 1¼-inch from the end of the main, I run about 2-inch pipe, say three or four feet, and then reduce to 1¼ inch with a coupling.

Professor Kinealy: You do not have the same trouble if only half of the radiation on the riser were working up to the same degree?

Mr. Schlemmer: You mean if the valves were turned off?

Professor Kinealy: Yes.

Mr. Schlemmer: I have not tried it.

Professor Kinealy: We find the same trouble in both hot air and hot blast work. The lower the velocity of the air passing through the main, the easier it is to deflect it into the branches.

Professor Hoffman: In speaking of the friction losses in the pipes, is Mr. Schlemmer dealing with pipes reamed smoothly on the inside or pipes having the usual burr?

Mr. Schlemmer: All of my work is on the specified reaming, but whether the steamfitter does it I do not know. My instructions, however, are very decided on that point, and my observations satisfy me that the work is being so installed.

Professor Hoffman: I asked that because I thought that the usual burr would change the proportion of his pipe areas very much.

Mr. Schlemmer: I find in my experience that the two-pipe system is the cheapest system to install. That could be proved,

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because in a two-pipe system the head to any radiator is proportioned to the height from the radiator tapping down to the medium line of the boiler. In a one-pipe system it is down to the main itself. The main in the latter case acts as a reservoir and is just the same as a boiler. As a consequence, on account of that difference in head in a one-pipe system, the tappings probably would be about one size larger throughout.

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## CLXXXIII.

# TOPICAL DISCUSSIONS.

### TOPIC NO. 1.

"The relative efficiency and velocity in two air pipes, one having a vertical rise of 18 inches to a round elbow supplying a pipe running horizontal for 10 feet, the other having a uniform upward inclination of 18 inches in 10 feet."

### TOPIC NO. 2.

"The difference in capacity to be provided in warm air pipes where air travels at different velocities."

### TOPIC NO. 3.

"The relative size of hot air pipes carrying the same volume of air at velocities of 100, 150, 200 and 300 feet per minute."

### DISCUSSION OF TOPICS 1, 2 AND 3.

Mr. G. D. Hoffman: With regard to the matter of velocity in a pipe with a vertical rise of 18 inches, having an horizontal lead of 10 feet, as against an inclined pipe running to the same point, I would say that the velocity would be very much greater in the inclined pipe as against the vertical pipe with a horizontal run. The cause of the velocity in a hot air pipe is simply the difference in specific gravity of a cold and hot column of air, the difference being so slight that the least obstruction tends to retard the velocity. My experience has been derived not so much from measuring the velocity of air currents through pipes similarly planned as in determining the freedom of air coming along the cold air duct. In a cold air duct, which is carried along the ceiling to a point adjacent to the furnace wherever there was a square turn in the direction of the air current at the point of drop, there would be a loss both in velocity and volume, but where the drop was made on an incline, a job that would not work at all where we had a square turn, would work perfectly if the air was brought in on a gradual incline towards the base of the furnace.

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Mr. Jas. Mackay: You are speaking of fresh-air inlets?

Mr. G. D. Hoffman: Yes, if that recipe was good in a cold air duct, it would seem to be equally applicable to a hot air duct or pipe, because the velocity of the air currents must be practically the same.

Mr. Lewis: Mr. Thompson, who started this argument, I believe, at the former meeting, illustrated a job in which I think the rise was something like 5 feet off of the top of the casing and horizontally something like 25 feet. This operated perfectly. The theory was that the column of warm air coming up out of the bonnet of the furnace in this vertical rise created a push effect that shoved the cool air through the pipe. The entry of the cold air, however, would be caused by the warm air getting lighter, causing atmospheric pressure to shove more air into the pipe. I believe there is value in this arrangement of piping in some instances.

Vice-President Mackay: It is simply the momentum created, but I think the same pipe would do better than if you went up 18 inches and then went on an incline.

Mr. G. D. Hoffman: I am somewhat of a vacuum crank on steam heating propositions at the present time, but I want to say positively that in the question of air moving there is no such thing as a vacuum in an air chamber. It is always the lifting power of the cold air that causes the warm air to move out of the furnace chamber, and it is always considered good practice in furnace heating to put on what is called a side collar connection in preference to top connections where the pipes have to run horizontally after leaving the top of the furnace. The only reason for using a top collar connection in low basements is simply on account of the head room. If there is room enough to get around the furnace, a side collar connection is almost always used by good furnace men to-day.

Mr. Chew: I want to support what Mr. Hoffman said. For a good many years I was sent to look after faulty furnace jobs east of the Mississippi river, and in cases where a man was not able to make a collar fit a cone top he put a flat top on the furnace. Sometimes he didn't leave any space between the top of the furnace and the top or the galvanized bonnet. I have ordered elbows that were put on flat tops cut down so that there was practically no rise, and made the throat as small as possible

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to give the incline to the pipe. When a man used a cone-top, he gained something further in cost, pitch of pipe and flow of air, than what he could get with an elbow. I favor the use of a pipe having a continued incline as compared with one having a vertical rise and horizontal run. In the case Mr. Lewis speaks about, that Mr. Thompson described, it was necessary to run the pipe in a church building across a room that was occupied, and the only way to do it was to run it with a considerable vertical rise at the start, a great deal more than is spoken of in this topic. He ran 60 feet, so it made me wonder whether my friend Thompson was giving us a fairy tale or not, but he has promised, some day to give in a paper a description of that furnace heating system; then we will have something more than a detail for consideration.

Mr. G. D. Hoffman: I really believe that with low velocities of air the two systems will be pretty nearly the same, but in instances where the velocity is fairly great, then the inclined pipe would have a distinct advantage over the vertical and horizontal pipe.

Mr. Donnelly: I remember that when this topic was discussed in Chicago, Mr. Thompson said the benefit, if any, came from the effect of using 45 degrees elbows rather than square elbows, and he did say that the longer the radius of the elbow, other things being equal, the better, but that when he used right-angle elbows they were with as long reaches as possible. All remember some of the first hot water plants that came after the boom of hot water heating, when they put in hot water plants down low. They didn't like to put in plants in the same way as was done with steam. It is not good practice to run hot water mains at an angle of 45 degrees a great distance, because it does not have a good appearance. If a vertical of 18 inches in a circuit were made, I think, under those conditions the circulation would be as good as if we run at an angle and brought the return pipe back at an angle. The same laws of velocity and friction apply. If you do get impact against a square elbow, you have to put a few more joints in the elbow and get around it. But I do not think we want to get back to these terrible rises and large pitch. Why is it necessary to have more pitch on hot water pipes than on hot air pipes? I do not think it necessary myself.

Vice-President Mackay: The question is really, under which condition can we obtain the best results. I have some informa-

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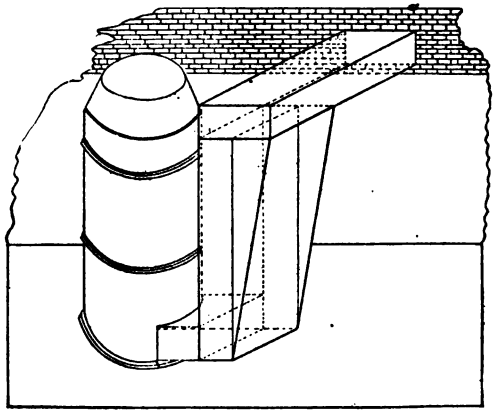
tion from one of the best informed warm air furnace men in the society. He compares warm air with hot water. Where the air is internally circulated and no air taken from outside, the circulation of air through the furnace is decidedly slower, so much so that it does not appear to circulate at all. A greater pitch in the air pipes will accelerate the velocity, but when the air is internally rotated you have no advantage over direct hot water. This statement suggests, what Mr. Lewis said this morning, that in heating school buildings, when the air is rotated, you may do the work with less fuel, but will not heat the school house so quickly in the morning.

Mr. Lewis: I agree with Mr. Donnelly, that the two are very much similar, water and air. It is the head that does the business. I had experience years ago in furnace heating. It was our custom, in heating school houses, to heat two rooms, one above the other with each furnace. One large flue led from the furnace to each room and turned out into the room, near the ceiling, and got fair action; but there was always a teacher's room over the stair landing, remote from the furnace, which gave trouble. We found that a horizontal pipe from the furnace to the vertical flue leading to the room seldom would work. We tried placing the vertical flue directly over the furnace, with a horizontal pipe at the second floor ceiling, and this did very much better.

Mr. G. D. Hoffman: The point Mr. Lewis raises is one that is familiar to almost anyone who is versed in hot air heating. That is, that it is always proper to introduce hot air through an



MR. HOFFMAN'S SKETCH.

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inlet located in the warmest part of the room. In Mr. Lewis' case he was not only greatly increasing the velocity of the air current, by making a long vertical run, but he also had the inlet in the warmest part of the room. It is a conceded fact that cold air offers much more resistance to the inflow of hot air through a register than warm air. It is also a conceded fact that a room is warmer near the ceiling than it is at the floor line, and it naturally follows that a hot air inlet located near the ceiling would have less air resistance than a register located at the floor level. This fact of cold air resistance to the inflow of hot air is so well known among furnace men that it has always been a mystery to me why steamfitters almost always locate indirect radiators, or rather an air outlet for them, in the coldest part of the room. An outlet from an indirect radiator should always be located in the warmest part of the room to be heated, because of the fact that it is warm air from the stack that is heating the room and not radiation. In other words, the air outlet from an indirect stack should always be so located that there would be no difficulty in passing the full capacity of the register into the room. To give an idea how small a thing will sometimes make a difference between success and failure of a job, I submit a sketch herewith which shows a cold air duct coming along the ceiling from the outside and dropping to the floor. The light lines show the box as it was originally constructed, and the heavy lines indicate the change that was made in the box. The job as first installed did not work. I could not get any air movement through the furnace, but after the change was made as indicated by the heavy line the job worked perfectly.

Mr. Chew: What was the relative shape?

Mr. G. D. Hoffman: The comparative shape was a parallelogram set into a square. The sketch shows the box as it was coming from the outside and the light lines indicate the way it was made. The only change I made in this duct was to construct it as indicated by the heavy line, so that as the air came in from the outside it simply fell into an opening the full size of the bottom of the box and slid along the inclined line into the furnace.

Mr. Jas. Mackay: Your vertical drop was of greater area than your horizontal?

Mr. G. D. Hoffman: Yes, three times as much.

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Mr. Oldacre: I had some experience about ten years ago on a job that involved this very question. I had a furnace on a 30-inch fire pot. There were twelve or fourteen pipes taken off the furnace, some led to the ground floor, some to the first floor, some to the second floor, and they were all given an equal pitch. The pipes were proportioned in what, at that time, was fairly good proportion, considering the size of the rooms. The upper floors received more heat than they should when the registers and dampers were wide open and everything operating; so, in order to correct the fault, the pipes which led to the upper floors were run straight up from the furnace. Mr. Donnelly said just now that hot air and hot water pipes were nearly similar. They are not as nearly similar as they might be, owing to the difference in velocity, since the velocity of water traveling through a pipe is a great deal less than the velocity of air. Elevating the pipes from a hot air furnace has given pretty good satisfaction.

Mr. Larsen: I think if it is only an 18-inch rise Mr. Hoffman is right and Mr. Lewis and Mr. Donnelly are also right if they can get head enough. If you get as much as four feet you are all right, but 18 inches will not help you much. If you get four or five feet or more you get head enough on a column of hot air to give you the draft you want.

Secretary Mackay: I was going to ask Mr. Lewis if he did not know that he would get a larger volume and greater velocity in a pipe graded upwards 18 inches in 10 feet than in a pipe running 10 feet horizontally and rising 18 inches, not overhead, on the second floor ceiling or anything of that sort. The second floor ceiling he describes is similar to the overhead hot water apparatus, because the head can fall the depth of the pipe, whatever that may be; it is falling down on the floor of the room. In the case described it is an upward incline from the furnace to the room; in either case, either upward 18 inches and horizontal, then into the room, or rising 18 inches, and while there is a similarity of circulation, I think what Mr. Oldacre says is true, the velocity is not as great and it makes a difference; I never was guilty of some of the things Mr. Donnelly describes, in placing hot water heating. In fact, I do not know that I ever exceeded a raise of 1 inch in 10 feet. I never found necessity for that, but where the distances were long I overcame it by enlarging

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the main. I never used long, sweeping elbows to help out, because I did not feel I had the headroom.

Mr. Charles G. Folsom (South Bend, Ind.): I hardly think that taking an 18-inch pipe in a raise of that kind, where other pipes are on the furnace, is good practice. We find that we cannot take horizontal pipe and run a pipe at right angles with it and have success. Usually we do not have the room to do it. In a house, if you are taking off several pipes, say 8, 12 or 15 pipes, you don't have a chance. It is not practical, we don't find it to work well. Taken off from the side in that way, it is what we call a robber if it does work at all, the rest of the pipes on the furnace do not work, even with a proper supply of air. The only way you could regulate it is by taking the combined area of all the pipes you take from the furnace and have your cold air supply equal to it. It depends altogether on the supply of the air. You must figure that way. This is a technical point on that one idea. We don't find it practical. I suppose I have fixed over 100 furnaces last year, repaired and fixed them so the pipes would work. We find all kinds of conditions, but we have cut out that idea of horizontal pipe taken from the top of the furnace, where you have your pipes on an incline.

Vice-President Mackay: The point is this: If they were all taken off 18 inches or all taken off an incline, which would be the best?

Mr. Folsom: Pipe taken off the top of the furnace never works as well as those taken off the side of the hood. That is what we have found in practice. We put the pipes directly on top of the furnace, and in many cases we have to put on the flaring bonnet. In that case the air seems to have more of an impetus.

Mr. Chew: Where a flat top is used the distance to the cellar collar is short, and if instead of using the flat top the cone top is used the pipes can start up from a lower level. The cone top does another thing; it gives space between the heating surface and the casing and a volume of air to fill all the pipes, while the flat top is so near the top heating surface that there is no air space and is not nearly so satisfactory in service. It is considerably better, where there is space, for the air to gather in sufficient volume to fill the pipe. Even when the air supply is deficient and the furnace is not hidebound, as they used to call it, but has plenty of air space, if there is not a gathering of air in the chamber at the

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top some pipe will not be properly supplied. The incline of the pipe which the cone top gives results in decidedly better service than the flat top with the elbows.

Mr. Lewis: Mr. Chew opens up a question of radiating surface which I think is important in furnaces. Radiant heat will not heat air. You have to rub the air against a warm surface to heat it. The radiant heat from the fire largely passes up over the fire. It is not so much the products of combustion inside of the radiator that heat it but this radiant heat which the radiator intercepts. The air rubs against the radiator and gets warm.

Mr. Folsom: Speaking about the horizontal pipe, 18 inches and then straight, I will cite a case we had where we could only use one pipe. The air duct was 200 per cent. more than the pipe could carry with the heat; that is the cold air duct coming under it. We found the cellar a great deal warmer than any room in the house, the cellar often up to 100. Of course, the air was choked off. It was a 22-inch pipe and it had a 24 by 30 air duct under it, so you see the unreasonable proportions. The furnace was large—too much radiation for the size of the pipes.

Mr. Larsen: May I ask a question that I think bears somewhat on the subject? Leaving out the question of a furnace, suppose we want to run an indirect radiator in place of a furnace, would it be better, in case we want to carry that air from an outside window into the basement, in say 35 feet, to put an indirect radiator near the opening at the intake, or near the base of the flue? Where would be the best place for the indirect radiator?

Vice-President Mackay: I should prefer placing the heating surface near the base of the flue, but should like to hear from someone who has had experience in placing it the other way. I think it would be best to place it near the flue, simply because there would be no loss of heat in transmission from the intake to the base of the flue; otherwise the air would to a certain extent be cooled by contact with the air in the cellar before reaching the indirect radiator.

Mr. Lewis: That goes back to our arguments as to where we should put the tempering coils on a blast plant. We put in the heating coils under the riser and registers, but in order to prevent the cold air chilling the floors of the rooms above, in the duct leading from the fresh air windows to the regular indirect

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radiators, we have additional tempering coils at the fresh air windows.

Vice-President Mackay: I would like to ask Mr. Capron where he would place the indirect radiator?

Mr. Capron: My practice has been to place it as near to the base of the flue as possible. Sometimes I have had a fairly long hot air duct. I think that is the proper place to put it.

Vice-President: Now as to Topic 2.

Mr. Chew: A paper was submitted to the Publication Committee a year ago, I think. There was some talk as to how fast air traveled in pipes. It was decided that it would be better to look into it a little more, and after the different members of the Board had conferred on the paper it was decided to send the paper back to the man, asking him to explain how he arrived at his conclusions. These two topics are proposed by that man. Evidently he wants information along those lines. He stated a certain number of cubic feet of air would travel through a given pipe in a certain time. He asks the same question, "The difference in capacity to be provided in warm air pipes where air travels at different velocities," and "The relative size of hot air pipes carrying the same volume of air at velocities of 100, 150 and 300 feet per minute"; so I hope some information will be given along that line. Help should be given that member, because the paper submitted was very well written, and all he wants is some proof for the conclusions he has reached, in order to send his paper along in better form. Whatever you give is an investment of your thought for the other man's use, and it will come back to you, figured out, later on.

Vice-President Mackay: No doubt there is a lack of information regarding air heated by convection through furnaces. Will someone present give up his experience?

Mr. G. D. Hoffman: The difference in velocities is in a great measure determined by the difference in temperature between the air in the warm air pipe and the air in the cold air duct. The greater this difference the greater the velocity in the warm air pipe and the greater the trouble in determining the capacity to be provided in warm air pipes. This question of difference in temperature between the air coming into the furnace and the air going out should always be taken into consideration.

Mr. Oldacre: I have made a number of experiments with

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anemometers as to the velocity of air coming through registers from hot air furnaces and blast systems, and, as far as the hot air furnaces are concerned, the velocity will vary greatly under different conditions. No stated rules could be put down as to the velocity of air coming from a hot air register. It depends not only upon the difference in temperature of outside and inside air, but very largely on the direction and velocity of the wind. If the air duct is proportioned to give two-thirds the area of the hot air pipe, as is sometimes done when the air is taken entirely from the outside, and if there is a good wind blowing, then there is an excessive velocity and a reduced temperature, so that there is no theoretical consideration by means of which it can be figured out. As near as I could find, after 200 tests, they varied so greatly with the same sizes, practically the same conditions, the same heights and the same elevations, that there seemed to be no method of arriving at any exact data.

Secretary Mackay. These three topics are intended to be, and are, propounded by their proponents, as relating solely to hot air taken in the ordinary way from a hot air furnace.

Mr. Wm. G. Snow: When I was engaged in the furnace business, some years ago, we used to allow roughly a velocity of say 250 to 275, possibly higher, to rooms on the first floor, and, roughly, a velocity of 400 feet in pipes leading to the second floor, and as a rule we did not allow much higher velocity to rooms on the third floor—perhaps 500 feet. These, of course, are very rough figures and, as Mr. Oldacre very aptly said, you can make 200 tests and get 200 different results, but taking it by and large, as the expression is, I really think the figures of 275 feet velocity through the furnace pipes, leading to the first floor, and 400 feet to those leading to the second floor, in severe winter conditions, represent perhaps, as nearly as may be, the velocities that you would expect to find if you tested it with an anemometer, averaging the velocities of all the registers on the first floor and all of those on the second floor. I will add one thing, that, in the finest residence I ever laid out, which was heated with indirect hot water all the way through, it worked very satisfactorily—the flues being proportioned on a basis of 275 feet velocity to the first floor, 375 to the second and 475 to the third.

Vice-President Mackay: That is hot water, indirect heating.

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Mr. Snow: Yes, but they were deep sections and it was a closed system, and the temperature was higher than you would get with the open tank system, therefore the flue velocities would be higher.

Vice-President Mackay: Would you have higher velocity owing to the higher temperature obtainable in warm air furnaces?

Mr. Snow: Yes, one naturally would, but the tendency nowadays is toward lower temperatures in heating, in every branch of the art.

Vice-President Mackay: Except hot air.

Mr. Snow: Well, I think it has been decidedly in favor of lower temperatures, in heating with hot air, as compared with years ago. As you know, when we were boys, when we put our hands over a hot air register, the temperature was terrific, but now we have our large registers and large pipes with lower temperatures, lower velocities, and better circulation. It takes more coal possibly, but the results are infinitely better than they were twenty-five years ago, and again the furnaces are so made that we can get the required volume of air through them, whereas formerly, to use the expression in the trade, they were "hide-bound."

Mr. Chew: Mr. President, I am glad to hear from Mr. Snow to that effect. Many people, in furnace heating, think, when we speak of hot air to-day, it means what they knew it to be years ago—hold a match near the register and it would ignite. In the last three or four years, particularly, there have been instances of furnace heating at much lower temperatures of the air at the registers. Two hundred degrees for hot air is to many young men in the trade preposterous, but I have seen that time and time again. I have boiled water 15 feet from a hot air furnace, in a tin cup, on a 14 x 20 floor register. That will give an idea of the high temperatures formerly possible, and I think more or less common with some classes of furnace work. So what Mr. Snow says, and the character of information that comes to us from all sources and from my observation, I am led to the conclusion that good furnace heating is done on lower temperatures than half a dozen years ago.

Vice-President Mackay: Which means they are using larger furnaces.

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Mr. Chew: That they are using larger furnaces, with better piping and lower temperatures.

Vice-President Mackay: Any further discussion on those topics?

Mr. Chew: What has been said, as far as I have heard it, has not given very much help to this man. A paper has been prepared that needs some change or verification of the statements, to be presented to the Society, and I hope what this man has asked for will be kept in mind, and at some future meeting the desired information will be given to him. He is working for a purpose.

Vice-President Mackay: In regard to the discussion of topics, I would like to say that it would seem that whether the topic deals with steam, hot water under pressure or open tank, hot blast or warm air, it should be of interest to all regardless of their specialties. The subject of heating by warm air, for instance, is one upon which very little reliable information is to be had. Data about velocities, sizes, heating surfaces, in this department of heating should be of interest to all. Mr. Chew's suggestion is a good one and we should keep it before us. There is hardly a week that passes which does not suggest to each one a topic for discussion which might be prepared for the society in a few spare moments.

## TOPIC NO. 4.

### "Air-Washers and Air-Cooling."

Mr. Chew: Mr. President, the topic came up by looking at a drawing that was put on the board by Mr. Lewis. The question was asked him, "Where would you put the air washer?" He said it could not be put in a system of that kind; that the system would have to be changed somewhat to allow the air washer to be put in. The next question that came up was, if the air was washed, would not the moisture in it under some conditions be frozen, with the arrangement suggested? Then the other question comes along, how would you get rid of the excessive humidity that would possibly be given to the air through the washing process, and Mr. Lewis asked if anybody had had any experience with the use of a brine coil to secure the precipitation of the moisture washed before it was passed to a building. Mr.

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Kauffman, of St. Louis, said that Professor Kinealy had some experience in the cooling of air after it was washed. Mr. Kinealy is here to speak for himself.

Professor Kinealy: The air washer must, of course, be put where cold air will not come in contact with the water that is used for washing the air; otherwise the washer would be frozen up. That means, of course, that the air washer must be placed between the tempering coil and the fan. In many cases it is advisable, and in some cases absolutely necessary, to have two tempering coils and have the air washer between the tempering coils; that is, we will have the inlet for the air, a tempering coil to heat the air above freezing point; then the air-purifying apparatus; then another tempering coil, and then the fan.

The purpose of the washer—and I do not like the word "washer," because that describes only a part of the apparatus. As a matter of fact, the apparatus that is installed to-day, and is usually called an air washer, is an air purifier. It not only washes the air and removes the dirt and dust, but it freshens and revivifies the air, so that in many cases one can save money by using an air washer. Instead of taking the air from the outside, the air in the building can be circulated, and by being made to pass through the air purifying apparatus, the peculiar smell that is found in badly ventilated rooms will be removed; the vitiated substance that comes from the breath of human beings will be removed; the air will be freshened and revivified and the air can be used over and over again. Of course it is not advisable to do that for too long a time. All washers consist of two parts, or rather, I should say, all air purifiers consist of two parts, the first being the washer, the second being the eliminator.

In the washer the air is made to come in contact with water and the dirt and dust is washed and removed from the air. If the air is made to come in contact with the water as intimately as it ought to, a part of the water is evaporated and this evaporation cools the air. We have an effect in the washer similar to the effect that we have in the air cooler that is used with a condensing apparatus, the difference being that in this case we cool the air, whereas in the cooling tower we cool the water. After the air has passed through the washer it passes into the eliminator, and there all entrained water is removed from the air, and such dust or dirt that may be carried forward with this entrained water is removed.

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We find that the smallest, finest, most disagreeable particles of dirt to handle are soot, and those particles of soot, as they pass through the washer, will be covered with water, forming a drop of water. If this drop of water is allowed to enter the building, it means depositing dirt in the building as well as water, and the object of the eliminator is to remove this water and also to remove the water that has no dirt in it. It is extremely difficult to determine how much dirt is taken out of the air. The only way that I know of, aside from making a chemical test, is to run the apparatus and see whether or not the walls near the registers are discolored. If the walls near the registers are discolored, then the dirt is not being taken from the air. We find always that the dirt that sticks to the wall of the room into which we blow the air is fine particles of soot. When dirt passes through the apparatus it may be due to a poor washer or it may be due to a poor eliminator.

As to what can be done with the washer in the way of cooling the air depends upon a great many conditions. There are times when the air can be cooled very much by being made to pass through the washer. There are other times when the air will be cooled but very little. In other words, if the humidity of the air, as it enters the washer, is high, then the air passing through the water cannot take up any water, cannot evaporate any water, and hence there will be very little cooling effect. If, on the contrary, the humidity of the air is comparatively low, then the air passing through the washer will take up water, will evaporate water, and the air will be cooled, because the cooling is done by the evaporation of the water. So that it is impossible to make a blanket guaranty as to the cooling of the air. There are times when the air can be cooled a considerable number of degrees, and again when it can be cooled but very little. The same way with the humidity. It is impossible to make a blanket guaranty as to the humidity of the air leaving the eliminator, for the reason that if the humidity of the air outside is 90 degrees, when it enters the washer, it will not be much less than 90 degrees when it leaves the eliminator. That is, of course, assuming that we have an air purifying apparatus, such as is ordinarily installed. If we have refrigerating pipes, so that we can cool the air and precipitate the moisture, we can have any humidity we choose when the air leaves the eliminator. In the winter time, we can

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cover a wider ground with the air purifying apparatus, because we start then with the air at a low temperature and heat it up to the desired temperature, and although it may be saturated at the low temperature, we can regulate the humidity almost as we choose. But there are conditions that we encounter in the summer time which, without special cooling apparatus, we cannot handle as well as we handle conditions in the winter time.

Mr. Jas. Mackay: Mr. Lewis advocated the elimination of the tempering coil in connection with a fan, and he was asked if it were necessary to use an air washer, where he would put it if he dispensed with the tempering coil. He advised using the tempering coil in connection with the air washer, but his idea was not to use a tempering coil with the ordinary installation.

Professor Kinealy: You may put in what I believe in Chicago is known as the Waters system. All the heating pipes are on the outlet side of the fan; and the washer is between the first bank of coils and the second.

Vice-President Mackay: On the other side of the fan?

Professor Kinealy: Yes. In winter time you have got to heat the air above freezing point, otherwise you will freeze the water. The water is used over and over again until it becomes foul and then is allowed to go to waste. The peculiar thing is that in the summer time, on a hot day, we will put water in the sump or the tank of the washer, pass the air through the washer, and the water will get colder. In other words, if the water, when we draw it from the hydrant and put it into the tank is, say 78 degrees, after the apparatus has been run a short time, an hour or so, all the water will be at a temperature of possibly 73, 74 or 75 degrees, depending entirely upon the temperature of the air and the humidity of the air and the amount of water in the air.

Professor Allen: I would like to ask Mr. Kinealy first what is considered the proper resistance of the air washer passing through it?

Professor Kinealy: The proper resistance is as little as you can get along with.

Professor Allen: How low can you get?

Professor Kinealy: I do not know how low you can get, but I can tell you how high. I have measured velocities of air passing through eliminators which varied all the way from 300 feet per minute up to 1,500 feet per minute.

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I advise you to get as near to 300 as you can. In the case where the velocity was 1,500, the average was 1,200. That, together with the small inlet, cut down the capacity of the fans something like one-third; possibly even more. But where the velocity is proper it will not cut the capacity down more than 10 or 20 per cent.

Professor Allen: My own experience with air washing has been somewhat limited, but I find resistance of the washer high. In one particular case, in order to obtain proper elimination of moisture, it was necessary to use a speed of 900 feet per minute. At this speed the resistance of the washer was 3-10 of an inch of water. This resistance necessitates a high speed of fan and of course results in added power in the fan. In this case it was rather higher than we had anticipated.

Professor Kinealy: That, of course, is a curious condition. I see at once what was the trouble. Under a given set of conditions with a certain amount of water pumped through the washer, if the air be made to pass rapidly through the water, it takes up a small amount of water and the eliminator has almost no work to do. That is what happened to you. If the air is made to pass through the water at a low velocity, it will take up a large amount of water, and if the eliminator is not doing the work as it ought to, the water will not be taken out of the air. If you run the pump slower, so as to cut down the amount of water, then you will not get water into the eliminator.

Professor Allen: Then you cut down the washer effect.

Professor Kinealy: Yes.

Mr. Theo. Weinshank: Professor Kinealy made a statement which I believe he would revise on second consideration. He said, make the velocity through the eliminator as little as you can. Let us carry this statement a step further and make the velocity zero. It is evident under such conditions no elimination will take place.

All of the air washers which we have at present on the market eliminate the moisture or the entrained water from the air either by inertia or by centrifugal force. Consequently, there ought to be a limit to the highest and lowest velocities desirable. From the number of tests that I have made, I have found that the limit must not be over 400 feet per minute velocity, nor less than 300 feet per minute.

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The question of cooling, or refrigeration, is very simple, and easily accomplished from a theoretical standpoint. If a relative humidity from 75 to 80 degrees is desirable, it can be obtained at a reasonable expense, but when a relative humidity of 50 degrees is required, then the expense of such an apparatus is almost prohibitive. Some years ago the Swift Company in Chicago undertook to ventilate their general office at the stock yards. They installed an air washer and operated it very satisfactorily during the winter months when the outside temperature was anywhere below 50 degrees. During these months they have kept the temperature in the tempering air chamber at about 50 degrees, using an automatic temperature regulator. During the summer months, when the temperature outside ran from 75 to 90 degrees, the humidity in the room became oppressive. As the company had a sufficient number of refrigerating pipes in the near vicinity, the space between the air washer eliminator and the suction of the fan was provided with 2-inch spiral galvanized iron pipes and brine pumped through them. By these means the moisture in the air was condensed and deposited on the pipes, but when the cost of the result was estimated and the temperature of the brine tested, this apparatus was immediately removed on account of the expense.

Prof Allen: If it is intended to cool the air by means of an air washer, can it be done by cooling the water in the washer itself by means of brine coils in the water tank?

Mr. Weinshank: Yes. On a certain air washer we used the same water over and over again. The tank of the air washer was about 24 inches wide, 6 feet long and 18 inches deep. The water in the tank was about 16 inches deep. We put in a cake of ice of about 100 pounds and thus reduced the temperature of the water from 76 to 64 degrees. After starting the fan, and after 5 minutes run, the temperature of the water went up to the original 76 degrees. Cooling of the air by means of an air washer can be accomplished, as Professor Kinealy said, assuming a total mixture of the air and water, but before anyone can tell the amount of reduction of the temperature in a room, one must know the temperature of the water, the temperature of the incoming air and the humidity of the air. It is almost impossible to state broadly that you can cool the air without taking into consideration the conditions as stated above. Brine

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coils in the water tank will reduce the temperature of the water the same as ice would, but in order to determine how much of brine or ice is to be used, the designer of an air washer must take as his starting point the temperature of the outside air, the desired temperature inside and the humidity of the air.

Professor Allen: Is it commercially desirable or possible, within the ordinary, reasonable expense for operation and installation, to cool the air, say 5 degrees, with an outside temperature of 90 degrees and a minimum of 80 degrees.

Mr. Chew: A paper was read before this Society some years ago on the "Cooling of the Auditorium of a School" in Pennsylvania by means of ice.

Mr. Weinshank: I have had some experience similar to that at Evansville, Indiana. At the opening of one of their theatres the engineer undertook to cool the building. The outside temperature was 85 degrees. They had a 110-inch fan blowing the air through a system of piping into the auditorium. The outside air was taken into a fan through a large galvanized iron duct, 6 feet wide and 8 feet high. In this duct they placed a number of wire baskets, and these baskets they filled with crushed ice. The baskets were so arranged that the air entering the fan had to pass over or through the ice. The engineer succeeded in reducing the temperature of the auditorium to 70 degrees, but it kept four icemen hauling ice to the building as fast as they could go.

Mr. Chew: Can you give an approximate idea of how much ice was used?

Mr. Weinshank: I cannot say, but I would judge about 20 tons. In fact, it is a matter of calculation, knowing the outside temperature to be 85 degrees and the inside temperature 70 degrees, and the fan handling about 20,000 cubic feet per minute.

Secretary Mackay: The case Mr. Chew refers to was the Scranton High School. The chief engineer of the Board of Control, of Scranton, presented the paper. The space cooled was something like 100,000 cubic feet; outside temperature was over 90 degrees, and they were able to maintain a temperature of 70 degrees during the commencement exercises with about five tons of ice, but they did not crack the ice. They put it in in whole cakes. They used this method that year and the following year also, and said it was satisfactory.

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Mr. Jas. Davis: Did Mr. Weinshank experiment in using water coils for the extraction of the humidity from the air after passing it through the washer?

Mr. Weinshank: On a certain test where the fan was blowing through the coils we circulated cold water through the heating coils and wasted it in the sewer. In this case the cost of water was not taken into consideration. The temperature of the water was about 55 or 60 degrees. After a run of one or two hours we noticed a considerable amount of moisture deposited on the pipes of the heating coils. The water which was circulated through the heating coils being cooler than that which was used in the air washer, we have succeeded in reducing the relative humidity and also reduced the temperature 4 or 5 degrees. This, of course, could not be taken as a basis of calculation, as there are very few places where water in such conditions could be wasted.

If the air washer is properly constructed and properly designed, it is my opinion that it is possible and practical to eliminate nearly 100 per cent. of the dirt in the air, even soot, etc., and it does not make any difference whether the air intake is at the sidewalk level or through a flue from the roof. It is my opinion that in the very near future, whenever a fan system of heating or ventilation is installed, that the air washer will become a part of the apparatus and will be treated in the same manner as the tempering or the heating coil. In other words, the air washer is an apparatus which has come to stay.

Professor Kinealy: As a matter of fact, it is a commercial possibility to cool the air as much as 5 degrees under the conditions stated by Professor Allen, but it is not a commercial possibility to undertake to cool it by the use of ice. Cool it by means of water from the hydrant. In St. Louis the water in the hydrant, in the mains, is usually in the neighborhood of 75 to 80 degrees in the summer. If that water be put into an air washer using the right proportion of water to the air and the washer is working as it ought to, the temperature of the air and the water will be reduced. As soon as the temperature of the water ceases to fall, empty out that water and put in new water. That is the way to cool the air. Water costs about 11 cents a thousand gallons, I think, and it is not an expensive proposition at all; it is simply a question of a little trouble.

Here is a thing that I am not yet able to explain, not yet sure

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of, but I will state it to you. I think that better results will be obtained by heating the water slightly rather than by cooling it with ice, for we find, as I stated, that if the water be at a temperature of 78 degrees, the water will be cooled until it falls to a temperature of 73 or 74 degrees. Then the water stays at that same temperature and the air stays at its same temperature. Putting ice in the water will not materially reduce the temperature of the air, for the simple reason that it appears that the cooling is due to the evaporation of the water, not to mere contact with the water.

Mr. Thomson: I would like to ask Professor Kinealy to sketch out his air washer. I understand he is the patentee of an air washer in general use—for the benefit of those who have not seen it and for myself, I would like to have him give a description of it. There are different air washers on the market, and the subject of eliminators is very important. I would like to see his eliminator particularly.

Professor Kinealy: I am perfectly willing to do it, but if I were presiding I would not allow it, as I think it is entirely out of order.

Vice President Mackay: I agree with you.

Professor Kinealy: I have studied the art very carefully. There is no literature on it. All the literature is in the patent office, and there have been a great many failures. One going back for years finds in the patent office attempts to purify the air and it is from these that we gather our information, and they point out the lines along which we need not work.

Without touching at all upon any patents I can briefly speak of the washers and of the eliminators. There are three methods disclosed in the art of washing the air. In the first method the air is made to pass through one or more sheets of water. Each sheet is made as complete as possible. In the other method the water is injected in the air in the form of a fine mist or spray, and flows in nearly the same direction as the air. In the third method the water is made to pass at right angles to the direction of flow of the air, and the water is made to assume, as near as possible, the same condition as rain in outside air, and with this rain there is a fine mist or spray. In the case of the eliminators, we have a modification of the old style centrifugal eliminator, based upon the idea that water, being heavier than air, if the air and water

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be made to rotate, the water will separate and pass to the outer circumference of the rotating vessel. The action is the same as in a dryer in a laundry. The wet clothes are put in a vessel and the vessel is rotated at a high velocity, and the water, by centrifugal force, passes to the outside. That is one method.

Another is where the air is deflected in a horizontal direction, from side to side, and the water is eliminated largely by contact with the surface along which the air moves and rubs. A third method is where the air is made to deflect alternately upward and downward, the object being to make the air go downward, then upward, and as the direction is suddenly changed from downward to upward, the heavier particles of water will fall down and the air will go up..

Then we have still another method, where the air, because of the shape of the eliminator, is set into motion in eddies, whirling at different points, in such a way as to combine the centrifugal action and the rubbing action of the air on a surface; the object being to get a combination of centrifugal and rubbing action.

That, briefly, is a statement of the art as it is to-day in connection with washers and eliminators; the two forming an air purifier.

Professor Allen: Professor Kinealy spoke of the fine soot passing through the eliminator. There has been conducted at the University of Michigan a series of experiments with washing of soot from the smoke. On the face of it this looks very attractive, but in actual practice I find that, while all the heavy particles can be removed, the appearance at the top of the chimney looks almost the same. This shows that in reality it is the very fine particles of carbon that give the dense black appearance to the smoke and not the heavy particles, and while these heavy particles may be removed in an air washer the fine particles pass through with very little reduction in their number.

Mr. Dougherty: There is one point I would like to have explained. The Professor recommended circulating the air in the building over and over. The only change I can see here is a chemical change. The washer, no doubt, will eliminate the organic matter and the vapor, but will it eliminate the carbon dioxide, and how would you remedy the decrease and the deficiency in oxygen? From that standpoint would it be advisable to continue circulating the same air in the building when it is increasing in carbon dioxide and decreasing in oxygen?

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Professor Kinealy: First of all, we know that the slight increase in carbon dioxide is not deleterious. For a change from six parts of carbon dioxide in 10,000 parts of air to ten or twenty parts of carbon dioxide in 10,000, the carbon dioxide itself is not deleterious; but we use that only as a measure to determine how vitiated the air is. The things that are deleterious really are the epithelium scales that come from the throat with the air we breathe out, the organic matter carried with the moisture. If we wash out from the air all this organic matter and the impure moisture, substituting for this moisture other moisture, we purify and revivify it, but we do not take out the carbon dioxide. That is why I said that it is not advisable to continue this recirculation too long. We know there are plenty of houses that are not aired more than once a day of 24 hours; and yet the occupants feel no bad effects.

Mr. Snow: I want to be enlightened on one point, by those who have had practical experience in installing air washers, in regard to the source of the air supply? Do they take it from the sidewalk level, in the case of city buildings, or take it, as has been the custom, before the common use of air washers, from a point higher up? From my experience it has not always been practicable to arrange such downcast flues in modern city buildings. I have in mind a bank building, put up in Boston, where an air washer was installed and the air is taken from the level of the sidewalk, avoiding the necessity of running up the vertical intake flue and makes a great saving in the cost of the installation.

I have had a little experience in taking air from the tops of buildings, and while theoretically that may be the source of the purest supply, yet, in several cases, I have had trouble from pulling smoke into the building when the wind was in a certain direction, or offending chimneys had been belching forth black smoke. Going to the top of the building we get into that difficulty, and by taking it near the sidewalk level we have the street dust to contend with.

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## TOPIC NO. 5.

"The chemical and physical properties of cast iron used in boilers and radiators."

### DISCUSSION

Mr. Chew: Several years ago one of our members read a paper—it is in the proceedings of 1905—and at that time he made the statement that some iron, as you bought it, did not make very good radiators, but it made very good boilers. For radiators the heat would not be transmitted as well as through some other mixtures of iron. I think his ideas and statements at that time did not receive very much respect. However, that discussion and that paper is in the proceedings of the Society. This topic is brought up at this time by another man. We have a number of people here who are qualified as manufacturers of boilers or radiators, or who are users of them, who may know something of the mixtures from which they were made, and certainly anything they have to add to the information already possessed will be looked upon as valuable in the proceedings.

Vice-President Mackay: I do not know what the topic is intended to bring out. There can be no question that there is a great difference in cast iron. Manufacturers use different mixtures. I do not think there can be much said against cast iron as a heat absorbing and heat emitting medium. There is a difference of opinion as to thickness and mixture of iron, but we have always found cast iron an excellent material for radiators and boilers. I would like to hear from some who have had experience in testing these metals. Professor Allen, you have had some experience.

Professor Allen: I think the form of the surface has far more to do with the amount of heat lost per sq. ft. of radiation than the material of which the radiating surface is made. The amount of heat transmitted through wrought iron pipe and through cast iron radiation of the same form and same thickness is practically the same. The particular point, it think, is that in most cases the metal is very thin and transmission through material is far more rapid than the convection from the surface of the radiator.

Vice-President Mackay: I think that is generally accepted; at least that is my experience. Some people believe, however,

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that you can use other and considerably thinner metal and obtain greater efficiency; of this there is no doubt in my mind. Have you had any experience, Professor Bull, in determining the value of the different metals?

Professor Bull: I thought the point of the paper was as to the chemical composition of the cast iron as affected by the heat. I would like information of that sort.

Vice-President Mackay: I believe the iron generally used is No. 2 foundry. Some makers mix with it considerable softener; others use less. Hard iron, under high temperatures, crystallizes, especially at right-angle turns, and is liable to fracture. But the iron used in making boilers to-day is of such a quality as to eliminate that condition.

Professor Bull: Is it not necessary to produce a good quality of iron to get a good boiler?

President Snyder: I think that is accepted.

Secretary Mackay: My opinion is, in making cast iron radiators and boilers, that the iron that will run freely is satisfactory for the uses to which it is put, that you cannot injure the iron with the fire while water is back of it, and that the radiator that is made from iron that will run commercially into a radiator is satisfactory for heating purposes, and that it is a mistake to assume that there is anything in a chemical analysis of that iron that would injure its properties as a heating medium or agent.

Mr. Weinshank: Since the explanation made by the former speaker, I would like to ask another question. Does the Society go on record as stating that the best cast iron makes the best radiators? If so, how can it be practicable from a commercial standpoint? We usually rate or estimate the cost of all apparatus made out of cast iron by its weight. We sometimes say that the cost of an engine will be about 15 cents a pound or so. Other castings will cost from 7 to 9 cents a pound. In other words, we come down to a thumb rule in estimating the cost of a certain apparatus or machine made of cast iron at so much per pound. Now since cast iron radiators are being sold in the market at about 21 cents per square foot, and a square foot being from 7 to 7½ pounds, it would bring the cost of cast iron to about 3 cents per pound including freight, etc.

If the manufacturers of radiators use good ore, or good cast iron, where do they come out at the end of a business year?

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Therefore, there must be an assumption that they use some scrap iron, and the above statement proves my contention.

Mr. Kauffman: I do not believe a radiator or boiler manufacturer can afford to use much scrap iron in the manufacture of the radiator, because it will be too hard, and everybody knows, if you get a hard casting, you will have very easy cracking in the milling of the radiator, and therefore I think every radiator manufacturer is aiming to get the best results and the best grades of iron to be had and the softest.

Secretary Mackay: I understood Mr. Weinshank to say that we, as a Society, stated that cast iron was the best material to make radiators from. We, as a Society, do not agree to anything of the kind and we do not agree that any metal is best for the purpose; and as to the question of putting scrap iron in, any manufacturer of radiators knows, they must use a certain amount of scrap to make the mixture, but they cannot use as much scrap as Mr. Weinshank intimates because of difficulties in castings when making the radiator. It must be soft enough to run without hard spots in it, and it must be soft enough to be milled and fitted at the joints. It is a commercial matter for the manufacturers, and for their self-preservation they will use a mixture that will run best.

## TOPIC NO. 6.

"The relative advantage of a wet or dry return to a boiler set at the end of a long narrow building in a gravity system, and the advantage of extending the main a long or short distance beyond the last radiator connection."

### DISCUSSION.

Mr. Donnelly: I would like to ask Secretary Mackay whether he knows what the propounder of this question meant when he said "relative advantage." Advantage in what respect? In first cost or economy of operation?

Secretary Mackay: In answer to Mr. Donnelly's question, my opinion is, in reading the question in the way the author propounded it, that he had had trouble with a steam heating apparatus where the boiler was located at one end of the building and he had a long steam main coupled with a long return back to the boiler, dropping down, and that he had trouble with lifting water

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in his last radiator. The question does not say so, but I have known of cases where they had similar trouble and the question seems that way to me. My experience and opinion is that it is often a case of too little water in the boiler for the amount of steam main or radiation that is on the boiler, and that part of the trouble is experienced by improperly venting that main. That people claim to have overcome the trouble by taking that dry return and making it a wet return. To my mind all that they are doing is increasing the volume of water in the system or supplying the volume of water that is necessary in the boiler originally, but was not there, and where they have used a bullhead tee, going up to a radiator or riser and to the dry return that they have lifted water to the last radiator, and putting what they call a pass-by a tee and going a short distance beyond that there was less possibility of lifting the water in that manner; and I think he wanted to know whether it was an advantage to go beyond the radiator any distance.

Mr. Weinshank: Mr. Donnelly said in reply to a question as to what he thinks is the best practice or the best advantage in having a wet or dry return to a boiler in a gravity system, whether he would drop after the last connection or whether he would run the pipe for a certain length and then drop. Mr. Donnelly answered the question, but it was not plain to me; therefore, I ask the question again. Mr. Donnelly says it all depends on the velocity. In order to make it more distinct, I will make the question as follows: Under the same condition, under the same pressure, which would be more advantageous, whether to drop immediately or drop after a certain length of space, after the last connection?

Mr. Donnelly: The question, it seems to me, is similar to the query whether a ball will go up into the air if you throw it. It will not unless you throw it high enough. The water will not go up unless the velocity be high enough. If it is properly laid out, in my opinion, such an expedient is not necessary. In other words, I give it as my opinion, that it is only where we come across a case of poor practice of steam pipe sizes, that we find the necessity of running past, and it is to cure a condition that ought not to exist that makes it necessary to do it.

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## TOPIC NO. 7.

"The benefits derived from the use of fusible plugs in cast iron steam boilers."

### DISCUSSION.

Secretary Mackay: Some of the states compel the use of fusible plugs in steam boilers, whether they use cast iron or steel boilers. From the way this member propounded the question, my opinion is that he has had some trouble with cast iron boilers that had fusible plugs in them; that is in spite of the fusible plugs, with low water, they cracked the boiler. I have had some experiences due to what I felt was a wrong placing of the plug. The plug melted out, but before the water could reach the opening, it cracked the section, and I have, after locating them in the crown sheet of the boiler, done away with the practice of putting them there. I had nothing to do with the propounding of the question, but I merely want to give you some experience in the construction of vertical cast iron boilers. The practice has been to put the plug in the crown sheet. You get the same crack with the fusible plug that you would without it. So that the plug in that case would not save the boiler. My practice is to place the fusible plug in the back section of the boiler below the crown sheet. When the water gets below that point in any part of the boiler it melts out the plug and the water is driven out by the pressure of the boiler. I have not had a single case of breakage in boilers with fusible plugs where they were located at that point, whereas I have had many cases where the boiler was fitted with fusible plugs, the plug was melted out and the sections were cracked by the admission of water after the melting out of the plug.

Vice-President Mackay: There are in different cities laws to regulate the location in a boiler of the fusible plug. The majority insist upon its being placed in the outer shell two inches below the water line or in the top of the shell with a pipe run down to a point two inches below the water line. In either case the plug is intended to fuse under a high steam temperature and is called a steam plug. Others put the plug in the fire chamber on the crown sheet or at some other convenient point. A plug in the fire chamber is usually a fire plug, *i. e.*, one that will fuse under

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the temperature of the fire. Some people use a steam plug in the water column with good results. There is a question as to whether a fusible plug is an advantage in a sectional boiler, run under 2 to 5 pounds steam pressure. I think the topic was intended to bring out an answer to this question.

Professor Kinealy: I have always looked upon the fusible plug as a sort of detector. If a fusible plug is placed in a boiler so that it will fuse or open, if the water is allowed to drop, say two inches below where it ought to, it means that when the plug is opened the owner of the boiler will know that the fireman has been derelict in his duty; as the fireman must go to someone in authority to get the plug replaced.

## TOPIC NO. 8.

"The advantages in efficiency and economy of one large or two smaller boilers for carrying the same large amount of radiation, assuming in either case ample capacity for the work."

### DISCUSSION.

Secretary Mackay: My experience and opinion is that you do not get the same economy in placing two boilers of small capacity on a given amount of radiation, unless one of the boilers is sufficient to carry the entire radiation without forcing in moderate weather. If you have 5,000 feet of radiation on your building, and you have two 3,000-feet boilers, there is never a time, even in moderate weather, when one of the two boilers is sufficient to carry the entire work, whereas at any time the larger boiler is large enough for the work and can be run under slower combustion during moderate weather and give all the results required, with greater economy, than one of the smaller boilers under either cold or moderate weather. In one case you must overtax the capacity of one boiler to carry the radiation. In the other case you never overtax your boiler.

Mr. Donnelly: In regard to this question, I know it has been the practice of one boiler concern in the East to recommend the use of two boilers, for rather peculiar reasons. They contend that it is good practice to get the air out of the radiators and keep it out, and they say the preferable way is to put in two boilers, each one ample to run it, and fire only one at a time, keep steam

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on by having one boiler under a bright fire while firing the other boiler, and only when the fire is burning up bright and making steam in the second boiler, to fire the previous one. When the heat is not desired they shut off the hot air register and let the indirect radiator stay full of steam. In that manner they have avoided a great deal of trouble due to automatic air valves; they never work but once, when they put steam in in the fall, and there is never air in again until they shut down in the spring.

Mr. Snow: Mr. Mackay's remarks apply, of course, to steam boilers. Whether the gentleman who propounded this question had in mind steam boilers or hot water boilers, as they are frequently called—although heaters is the proper term for them —is the question. I have in mind a case where a hot water system was put in with two boilers and the complaint was made that they were burning an excessive amount of fuel. Along about in November we found they were using both boilers. We said, " Shut down one boiler," and the result was, up to the middle of December, when the weather was not so severe as to require two boilers, the saving in fuel was considerable. So. Mr. Mackay's remarks with regard to the single boiler being of sufficient capacity to carry all the radiation, applies to steam heating, but would not apply so well to hot water heating. I have found a decided gain by having two boilers in place of one, running under bright brisk fire under one boiler in preference to running two fires sluggishly.

Secretary Mackay: I know the gentleman who propounded the question put it in connection with steam boilers. My way of overcoming the extreme size of one boiler has been—and I have done it with very good success—to have two shaking bars on my grate, so I could shake the front and back, or both as I wished, in moderate weather the back half of the grate can be left closed and you get combustion and air at the front of fire-box and don't lose by leakage; and I have found that on a large boiler it is quite satisfactory to give you all the results you require in moderate weather, without the combustion of fuel, which a large grate would give you.

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## TOPIC NO. 9.

"The comparative fuel consumption of fire-box boilers in brick setting and horizontal tubular boilers."

## TOPIC NO. 10.

"The size of standard fire-box boilers which should be provided to supply 1,500 pounds of steam per hour for direct radiation at three pounds pressure, burning hard coal with a 60-foot chimney and good draft."

## DISCUSSION OF TOPICS 9 AND 10.

Mr. Lewis: In the Eastern part of the United States, when I was in general conversation with some steamfitters and engineers they seemed to feel that a fire-box boiler was not a good boiler. Out here we use a good many of them, particularly in Chicago. In heating apartment houses they are used very extensively. I have known a number of instances where they are very satisfactory. I want to hear what the Eastern men have to say about the use of fire-box boilers. What proportion of the rated heating surface is it fair to allow a fire-box boiler, brick set, with the products of combustion circulating around the outside?

Mr. Larsen: Mr. President, I am not from the East, as Mr. Lewis has said, I have never been any farther east than here; but I am opposed to a fire-box boiler, for the reason of the experience I have had with them. I can get better results from a tubular boiler set in brick than I can from a fire-box. The only reason that I can discover for that is that I cannot get my gases to the proper heat for combustion in a fire-box boiler on account of the close proximity of the water to the fire. I have never been able to get the gases to the proper heat of good combustion in the fire-box. While I was State Boiler Inspector for the State of Minnesota I ran across a case of a man in a certain county who had a saw-mill with a fire-box boiler. He would not have me inspect it, because, he said, it wasn't large enough. He was going to trade it off and get a bigger one. I told him I would inspect the boiler and give him some advice if he would take it. He said, "What is it?" I said, "If you will turn that boiler around and put the grates in the other end, and set it in brick, you will have plenty of steam." He said, "How do you mean?"

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I gave him a sketch of how to set his boiler and have the grates in the other end and let the gases pass through the fire-box and use the box for a combustion chamber, and told him that if it didn't work I wouldn't charge him anything. He said, "All right." Inside of two weeks I came back that way and he had the boiler all fixed up and it was working very well. He paid me for the inspection and thanked me for the advice.

Mr. Snow: I would like to ask Mr. Larsen what kind of coal he burns up there.

Mr. Larsen: We burn wood. I stated this was in a saw-mill and he had nothing but slabs, and saw-dust to burn.

Mr. Snow: I should have said fuel, perhaps. Mr. Lewis probably found, in talking with the people in the East, that they preferred to use the horizontal tubular boiler, over the fire-box boiler; that they criticised the short fire or flue travel, whereas with the horizontal tubular boiler the gases go under the boiler and then through the tubes, giving a longer time for contact of the gases with the water.

Mr. Lewis: I have never been able to get any real good reason from the East why the fire-box boiler would not be all right. I never could learn any reason for it, and they are using many cast-iron boilers, and many of the same conditions occur in both fire-box and cast-iron boilers.

## TOPIC NO. II.

"It is said to be a fact that many houses built to sell are now fitted with hot air furnaces that take all their air from the hall and none from out of doors. If so, what can be done by our society to stop the practice?"

## DISCUSSION.

Mr. Oldacre: Possibly Mr. Chew is familiar with a proportion of what I will say in regard to that matter, and that is, as far as my experience is concerned, I have always opposed rotating air where people have got to live continuously. It may be all right in churches or auditoriums before the people occupy the space, but during the time the space is being occupied I do not believe in rotating air, and I do not believe any successful method of heating from any standpoint has taken the air from the outside. I agree with what the topic seems to set forth—it is pernicious.

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It is done by many people in the Central West, particularly; it is practiced in Canada, but I am happy to say there is very little hot air down in Canada, because it will not heat there. Some few years ago I was in Brockville and a gentleman took me around to show me a heating plant he was putting in with this rotating system, taking air from two rooms and one hall. That day the thermometer stood 30 degrees below zero in the forenoon; in the afternoon it was 14 degrees below. The gentleman took me to the house and introduced me to his wife; said he wanted to show me the circulating system they had put in this house. The lady turned around and said, "Don't you know that last fall we had that torn out and brought the air from the outside?" It was impossible to heat this house with the circulating system. So from a practical or commercial standpoint and from the sanitary or health standpoint I thoroughly believe in any method that will prevent circulation of the air during the time the house is being heated.

Mr. Chew: The feeling of the society on this point was very positively set forth at the meeting at Chicago a year or two ago when the meeting supported Professor Carpenter in his statement that the furnace system was abused on account of the over-ventilation. The opinion was expressed that there was no occasion to ventilate to the extent which the furnace system did ventilate, and for that reason the rotation of the air, in his opinion and in the opinion of the society at that meeting—at least they assented to the position of Professor Carpenter that the circulation of air was not a pernicious system by any means, but was on a par with the system of direct hot water or steam heating. It has been stated to me by a good furnace man that the circulation of the air through the furnace system when being rotated was much more sluggish than the flow of air on the other plan, and in the West, where the circulation of air is largely practiced, they succeed in heating houses in extremely cold weather by that method, and in the fall and spring they take the air from outdoors. There is a very substantial saving in fuel when over-ventilation is avoided by circulating the air, said by some to be as much as 20 per cent.

President Snyder: The point is, what can be done by our society to stop the practice?

Mr. Chew: It is a question whether it needs to be stopped and

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whether it should be encouraged in the interest of fuel economy and cleanliness for the benefit of the public. The man who asked the question should not have asked it in that way. The dwelling house is occupied by one woman, possibly a servant girl and a couple of children, who will have 20,000 to 30,000 cubic feet of air. That is a great deal of air for 2 or 3 people to live in as compared with what they would have in a church or a school; so the necessity for ventilation is not so great as he thinks. Besides, it is common to assume that air leakage in heated buildings amounts to at least one change of air per hour. The necessity does not exist in connection with furnace any more than with other methods of heating which provide for no change of air whatever. I strongly advocate the use of an air supply system, which would provide for taking air from out-of-doors during the spring and fall months and to shut off the outside supply and take the air from the hall or some room at other times of the year when the weather is extremely severe for short spells and the temperature out of doors is zero or below. Another important thing, from a sanitary view point: When air is taken from out-of-doors it fills the house with dust and dirt and all the germs, which later students find in larger numbers and a greater menace in dust than in the air from sewers. The dust carried in with an outside air supply costs money for cleaning carpets, tapestry, etc., and it is an item of considerable moment to the man who has to finance the family. This subject was treated in a paper on "Things to Consider in Furnace Work," read before the National Association of Master Sheet Metal Workers, by Henry A. Stumpf, a successful furnace man of 40 years of experience and careful study. From his paper the following is an extract: "I want to say something about inside air ducts. When I get a customer and say anything about inside air he will tell me that he would not have a furnace with an inside air duct. When asked his reason, this is invariably his answer: 'I want ventilation; the inside air will be impure.' I wish to state this fact, that with an inside air duct in our crowded and dusty and often smoky cities the inside air is cleaner, purer and more wholesome than the outside air. Why? Because you are not sucking in the dust from the streets and soot particles from your neighbor's chimneys. The air you are using is air from your own rooms, free of dust, soot and smoke."

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I have spoken freely for a purpose. I do not wish to be misunderstood. I have no desire to be put in a false position for presenting information which I feel the society should have. I positively favor the use of the best air obtainable and that comes from out of doors. I fully realize that this air carries with it some things against which safeguards are needed but not ordinarily provided. Contact with the furnace firepot burns alike the germs from the outside and the organic impurities thrown off by the occupants of a building. In the spring and fall outside air should invariably be used, but if the heating plant is small there is no occasion for it to be burned out and fuel consumed wastefully without making a home comfortable when all can be changed by simply circulating the air for a season when the walls, windows and doors are breathing at the rate of one or more changes of air every hour.

I think the question raised is like many another bugaboo.

Vice-President Mackay: Mr. Snow was guilty of writing a book on furnace heating. He may be able to say something on the subject.

Mr. Snow: Yes; and I mentioned that if we provided a return inlet, it was human nature for people to use the warm air all the time and get nothing from the outside. Therefore I frowned it down; I said it would be better to pay for the heating of the cold air. With intelligent management, however, there is no objection to the use of a return air duct at night, when windows in sleeping rooms are raised.

## TOPIC NO 12.

### "The Steam Loop and the Return Trap."

Mr. G. D. Hoffman: About a year ago a gentleman from New Orleans came into our office and said he was very anxious to heat his house with steam, but owing to the fact that there were no cellars in that locality, he would be compelled to locate the boiler on the same level with the radiators, if he placed the radiators on the floor, and the question was asked me if steam could be circulated through radiators on the same level with the boiler. The accompanying sketch is my reply to the query:

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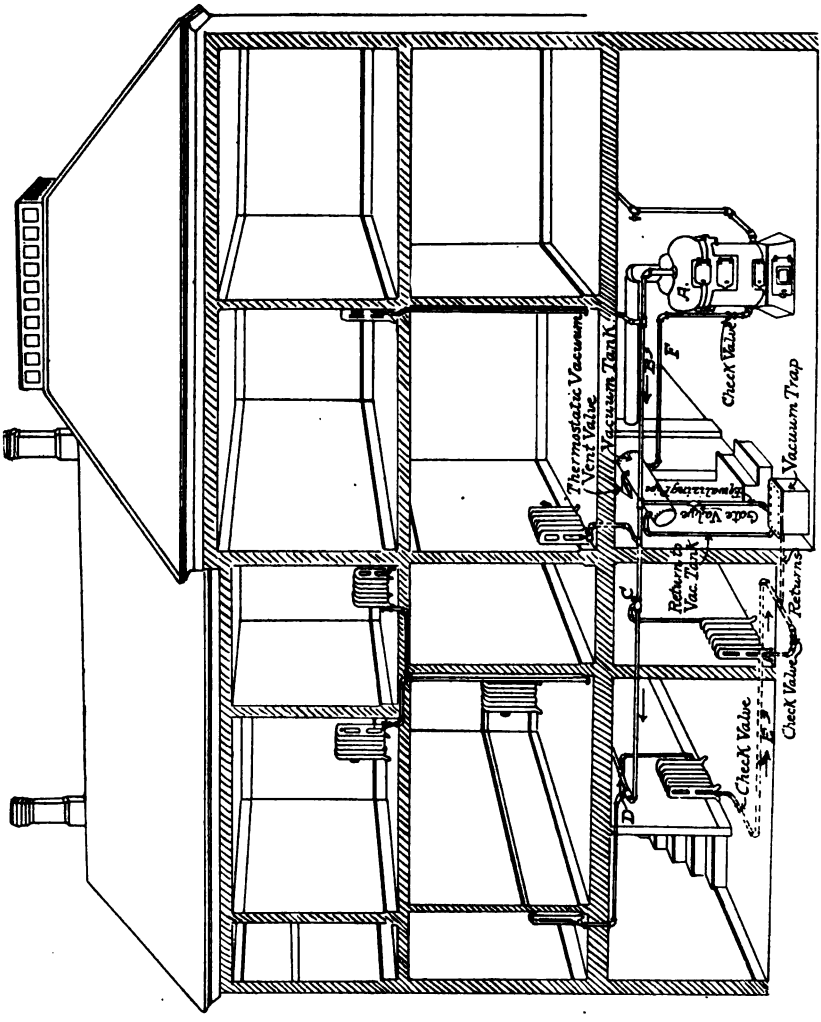


MR. HOFFMAN'S SYSTEM OF CIRCULATING STEAM THROUGH RADIATORS ON THE SAME LEVEL AS THE BOILER.

"A" is the boiler. "B" is the heating main with steam flowing in the direction of the arrow. When steam reaches the points "C" and "D" it flows into the radiators connected at these points the same as if the radiators were connected on the floor above. The only trouble with a connection of this kind, originally speaking, would be that the radiators would soon fill with water from condensation. In the accompanying sketch it will be noted that the radiators are connected by means of pipe "E" to a vacuum trap, and the pipe "E" is so inclined that the water of condensation flows by gravity into the vacuum trap.

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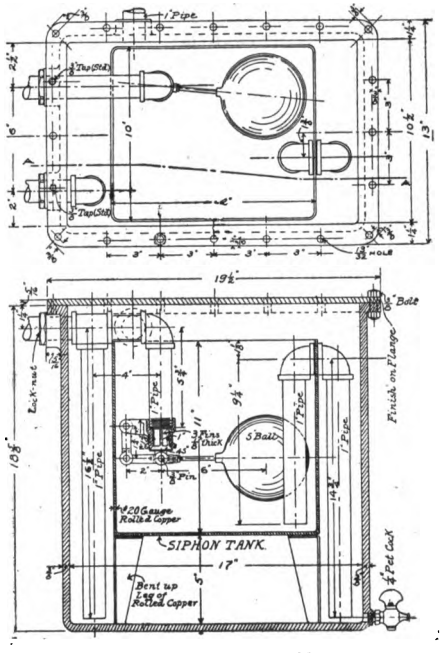
This vacuum trap has two other pipes leading into it, one of which is called the equalizing pipe, which is directly connected to the steam main. The other pipe is called the return pipe to vacuum tank and leads from the vacuum trap to the top of a tank designated "Vacuum Tank" in the drawing, which is located at a point considerably above the water line in the boiler. Inside of the vacuum trap, as shown by the detailed drawing, is placed an open pan in which is located a float valve which controls the return to the vacuum tank.




DETAILS OF VACUUM TRAP.

It will be noted that the equalizing pipe from the live steam main opens directly into the top of the vacuum trap, and the steam from this pipe, which the open pan in the vacuum trap is emptied and the float valve open, passes directly from the equalizing pipe through this float valve into a vacuum tank, expelling all of the air in this vacuum tank through the thermostatic vent valve which is located on the top of the vacuum tank. As the water of condensation flows through the pipe "E" into the vacuum trap it in time overflows into this open pan until it is of sufficient height in the pan to close the float valve.

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It will also be noted that a connection is made to the bottom of the vacuum trap from the return pipe to the vacuum tank outside of the open pan. This pipe is open at its lower end, but when the trap is full of water this pipe is submerged. When, as above noted, the water in the open pan closes the float valve, the steam in the vacuum tank begins to condense, with a consequent reduction of pressure in this tank. The thermostatic vent valve on the top of the vacuum tank is also a vacuum valve; that is, a valve which automatically closes against the ingress of air into this tank as pressure goes off.

The result of this reduced pressure in the vacuum tank is an unbalancing of the pressures in the vacuum tank and in the vacuum trap with a result that as soon as the difference in pressure between the vacuum tank and the vacuum trap equalizes the weight of the column of water in the return pipe from the vacuum trap the water will begin to flow from the vacuum trap into the vacuum tank. As soon as all of the water is displaced in the main part of the vacuum trap the syphon shown in connection with the open pan in the vacuum trap dumps the water out of this pan into the main part of the trap. The float valve, having nothing to support it, opens which immediately permits an equalization of pressure between the vacuum trap and the vacuum tank, and as the pressure on the vacuum trap is equal to that of the boiler the water in the vacuum tank will then flow back by gravity through pipe "F" to the boiler. Of course it is possible to do this same thing with several kinds of traps, but on all of the traps I know of you have to have a certain amount of pressure in order to operate them. With this device you do not have any pressure at all, practically speaking. Anything above a half pound will operate it perfectly.

Mr. Chew: Is it a tank within a tank?

Mr. G. D. Hoffman: No, an open pan.

Mr. Jas. Mackay: Is not this an application of the steam loop?

Mr. G. D. Hoffman: In one way, yes, only I use vacuum in the upper tank to pull the water out of the trap.

Vice-President Mackay: A vacuum is created, drawing condensation from the radiators up and discharging it into the boiler —the top part of a steam loop.

Mr. Donnelly: If information is wanted on the steam loop,

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Mr. Blessing, of Albany, who invented it, will probably give it. He has recently published a booklet giving the history of the steam loop and a history of the return trap, and Mr. Hoffman has given that with little variations. The matter of proportions relates to the proportions of condensing power of the tank. You have got enough steam to elevate the water and that can be done irrespective of the pressure. You can blow the air out of the tank and have a vacuum in it by condensation of the steam, and it is entirely independent of the fact whether it is above or below atmospheric pressure.

## DISCUSSION OF THE STEAM LOOP.

Professor J. D. Hoffman: It looks very much as though Mr. Hoffman has an application of the steam loop, as was suggested. We know that when properly proportioned it will work in about the place he has shown. The difficult feature in the application of the steam loop is to know the proper relation between the areas of the two legs of the loop. We need more information concerning the design of the steam loop, and I believe this problem is right along that line.

Vice-President Mackay: Has anyone here had experience with the steam loop?

Mr. Snow: If anyone wishes to look into the steam loop, he will find an interesting paper written by Mr. Walter C. Kerr, published some years ago, in the Transactions of the Society of Mechanical Engineers.

Vice-President Mackay: Has anyone else anything to say on this subject? The steam loop was controlled and probably is now by the Westinghouse-Church-Kerr Company.

Mr. Donnelly: Yes, the steam loop was bought under the Blessing patent.

Mr. Snow: Mr. Kerr is president of the Westinghouse-Church-Kerr Co., in New York. When I was in Philadelphia, we put the steam loop in the Bellevue Stratford Hotel, which is to-day a representative piece of work, eliminating all traps.

Vice-President Mackay: It worked satisfactorily, did it?

Mr. Snow: Yes; we never had any trouble in that particular instance at all, and never had any trouble with it elsewhere. That was a good sized installation for a city building. Another point

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that may be of some interest, is that we used no separators whatever. We used a combined muffler tank and separator through which the exhaust steam passed before reaching the distributing mains. The high-pressure piping is laid out with a complete ring or loop and a cut-out valve between every two pieces of apparatus, whether boilers or engines. Where the pipe rises to come over to an engine a cross is used, and in every one of those is a drip point connected with the steam loop.

Vice-President Mackay: Is the muffler tank also drained?

Mr. Snow: Yes, it is merely a big tank at the base of an 18-inch exhaust riser, an overhead feed system is provided in the attic, distributing through the different wings of the building.

(The above discussion brought out the suggestion that drawings and a description of the steam loop should be presented in the Proceedings of the Society, and the following history and explanation of its construction and operation by James H. Blessing, is therefore reprinted from the *Engineering Review* of September, 1907.)

### THE STEAM LOOP.

The Steam Loop is a device for returning the water of condensation from a heating system, located below the water level of the boiler, directly back into the boiler without in any way opening to the atmosphere.

Under favorable conditions the steam loop will work as well as though the heating system were placed high enough above the water level in the boiler to permit all the water of condensation to gravitate back into the boiler.

In a general way the mode of operation of the loop is this: The heating system is so arranged that the water of condensation from the different radiators gravitates towards some low point and thence is led into the top of a receiver. After this is done it is found that owing to friction, caused by the velocity of the steam passing through the different pipes and condensation due to radiation, the steam pressure in the small drip receiver is much less than that in the boiler. This difference will determine the height or the length of the loop, that must be employed so that the water will gravitate through it into the boiler; that is to say, if there is ten pounds difference in pressure,

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the descending leg of the loop should extend about thirty feet above the water-level in the boiler, since a column of water two and three-tenths of a foot high is equal to one pound pressure, and, given a difference in pressure of ten pounds, it would require a column of water twenty-three feet high to equal this difference in pressure. If we make the loop thirty feet high we shall have an additional length of seven feet with which to overcome friction. The water, after it reaches the top of the loop, composed of a larger section of pipe, will flow into the boiler through the descending leg with a velocity due to the extra seven feet added to the discharging leg.

Some of the steam loops that have been in use were constructed similar to the sketch, Fig. 1. This style of steam loop was brought to the attention of the public about 1890. In the loop shown in the cut it is not necessary to use a receiver to contain the water from many radiators as there is only one shown.

Referring to the cut: 1, is the boiler; 2 the radiator; 3, the drip pipe from the radiator; 4, the return leg; 5, a short piece of pipe larger than the receiving or discharging leg, which forms the receiver, or separator; 6, is the main steam pipe for supplying the system; 7, is a check-valve opening towards the boiler to prevent the water returning to the system; 8 and 9 are hand valves used on occasions that will be explained later.

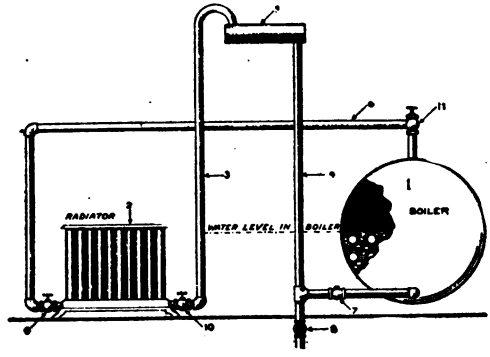


FIG 1.—THE STEAM LOOP.

To start the loop in operation with steam in the boiler, we first open steam hand valve 9 to admit steam into the radiator, then open steam hand valve 8 that opens to the atmosphere and the steam entering the radiator will displace the air and

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water from the radiator up through the drip pipe 3 into the top side of the large pipe 5, and so on down through the discharging leg 4 that leads from the bottom of the large pipe 5 and so on through the hand valve 8 to the atmosphere. When the air and first water have been removed from the system, close the hand valve 8 and after the discharging leg of the loop has become nearly full of the water of condensation, the circulation will continue through the check valve 7 into the boiler. This circulation will continue so long as there is no air or an unusual flood of water, for when this happens, pipe 3 will fill solid with water. Under these conditions pipes 3 and 4 (the two legs of the loop) are equal, one balancing the other, and the circulation stops until the equilibrium is displaced by blowing through as has been before described.

During the year 1870 the proprietors of the Townsend works at Albany, N. Y., deemed it best to remove their establishment down to the river front. I concluded to use the exhaust steam for heating the foundry and part of the upper floors, and to heat the offices, machine and pattern shops with direct steam taken from a boiler to be specially installed for that purpose. I intended that the boiler should be set in a pit so that the water of condensation from the heating system of the lower floors would gravitate into it. I did not discover the gross error I had made until after nearly all the work was done, with the exception of the setting of the boiler, when I learned how impracticable it was to place the boiler low enough to have the water from the lower floors gravitate into it owing to the fact that each tide caused the level of the water in the river to rise higher than the fire box of the boiler. In order to overcome this condition it would be necessary to set the boiler in a tank anchored to prevent its floating. This would have been very expensive and under the circumstances impossible.

While working on this problem, it occurred to me that after all the coils and radiators were only a part of the direct steam pipe that conveyed the steam from the boiler through them and finally terminated in the small pipes used for collecting the water of condensation.

If this smaller return pipe were connected, so I reasoned, to the top of a vessel of proper size placed a certain distance above the water level of the boiler, the water and steam would

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pass over into such a receiver, the water falling to the bottom and separating itself from the steam. The steam pressure in the receiving vessel would be about the same as the pressure in the system at its farthest point from the boiler. If this pressure were near enough to that in the boiler and the receiver were placed at a height sufficient above the water level in the boiler so that the solid water column would make up for the difference in the pressures, the water would gravitate back into the boiler through a return pipe extending from the bottom of the receiver. With this understanding of the conditions, I prepared a spherical vessel twelve inches in diameter as the receiver to be used in the system with which I was experimenting. I believed that a receiver of the size mentioned would be ample for the purpose as the capacity was less than one gallon per minute. The receiver was placed on the floor above the boiler where the coils were situated and about nine feet above the water level in the boiler. After the receiver was connected up and steam turned on and the first water and air removed by blowing to the atmosphere, circulation began and was perfectly maintained. This, I believe, was the first steam loop ever made to return the water of condensation from a steam system situated below the water level of the boiler whence the water issued in the form of steam, all without in any way opening to the atmosphere.

For a very special application of the device patented February 13, 1872, letters patent were granted to me on December 28, 1883. Fig. 2 here shown was taken from the patent papers and is a very good representation of the device: It shows a boiler and system of pipes and radiators, a part of the system being above

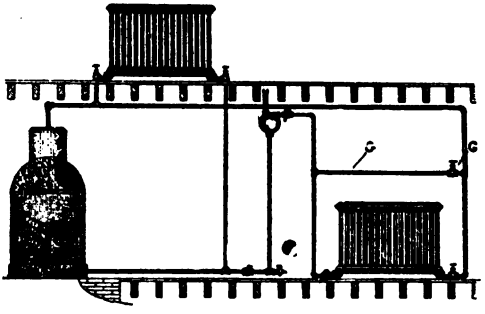

FIG. 2.—CUT SHOWING GRAVITY AND LOOP SYSTEMS.

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the water level in the boiler and a part below. The water of condensation from the system above the water level of the boiler is arranged so as to gravitate back into the boiler. The other part of the system is on the same level with the boiler, the water being returned to the boiler by means of a special device, covered in the patent reissued in 1873, the only exception being that instead of blowing out the first water of condensation to start the circulation, an effort is made to save all the water condensed. To this end, it will be noticed, a direct steam pipe is taken from the main steam supply pipe and connected with the top of a spherical receiver. The supply pipe connected with the spherical receiver has attached to it a stop-valve G, operated by hand a few times until the first water of condensation is removed from the radiators and the circulation established, after which the stop-valve G may be closed and the circulation will continue as long as the steam pressure in the system is kept up.

The reader may be constrained to ask: "What is the difference between the 'steam loop' and the return steam trap? The mode of returning the water is the same in both. Without opening to the atmosphere and without any loss, both return the water of condensation to the boiler whence it issued in the form of steam and at a temperature only a few degrees less than that of the steam itself." In answer it may be said that the only difference between the two methods is in the way in which the equalizing of the pressures for returning the water is accomplished. In the case of the "steam loop," the height of the returning water column must be great enough to make up for any difference in pressure that may be between the boiler and its steam system, *e. g.*, if the difference in the steam pressure between a certain boiler and its system of distribution is ten pounds, the height of the return water column in the steam loop would need to be from twenty-five to forty feet above the water level in the boiler in order to maintain a circulation. With the return trap the difference in pressure is equalized, not by the length of a return water column, but by means of steam taken direct from the boiler. It is not found necessary, therefore, to place the trap so high above the water level in the boiler.

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Dunn, Wm. A., 42 Mechanic St.....Newark, N. J.
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Edgar, A. C., 929 Chestnut St.....Philadelphia, Pa.
England, Geo. D., 3289 Broadway.....New York.

Farnham, Geo. D., 522 West 112th St.....New York.
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Fortune, Chas. W., care Sheldons Limited...Galt, Ont., Canada.
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Harrison, B. S., 11 East 24th St.....New York.
Harvey, Andrew, 28 First St. (Pres., 1904).....Detroit, Mich.
Hasey, Chas. E., 310 Third Ave.....Minneapolis, Minn.
Haskins, Elbert O., 201 Irving Place.....Rutherford, N. J.
Hauss, Chas. F., 24 rue de Mogador.....Paris, France.
Hellerman, Harry H., 312 Cherry St.....Philadelphia, Pa.
Hemingway, Wm. S., 118 Fifth Ave.....New York.
Hoffman, Geo. D., 282 Michigan Ave.....Chicago, Ill.
Hoffman, Prof. J. D., Purdue University.....Lafayette, Ind.
Houston, Fred K.....Rockford, Ill.
Hudson, P. S., 179 Lake St.....Chicago, Ill.

Ingalls, F. D. B., 106 E. Fayette St.....Syracuse, N. Y.

Jeffreys, John, 11 Old Queen St....Westminster, London, Eng.
Jellett, Stewart A.,
Broad & Wallace Sts. (Pres., 1895)....Philadelphia, Pa.
Jennins, Henry Horwood,
West Hill, Chapeltown Road.....Leeds, England.
Jewett, Frank N., 1625 Marquette Bldg.....Chicago, Ill.
Johnson, Warren S., Michigan St.....Milwaukee, Wis.
Jones, Almon O.....Battle Creek, Mich.

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Jones, Walter, Holly Mount.....Stourbridge, England.
Joslin, Herbert A., 156 Fifth Ave.....New York.

Kauffman, Samuel, 2320 Olive St.....St. Louis, Mo.
Kehm, August, 226 E. Kinzie St.....Chicago, Ill.
Kellogg, Albert T.....Kewanee, Ill.
Kenrick, Alfred E.,
214 Washington St. (Pres., 1902).....Brookline, Mass.
Kent, James M., Manual Training High
School.....Kansas City, Mo.
Kent, Prof. Wm.,
601 Comstock Ave. (Pres., 1905).....Syracuse, N. Y.
Kerr, Frank E., 157 West 111th Place.....Chicago, Ill.
Kiewitz, Conway, 409 East 51st St.....New York.
Kinealy, Prof. J. H.,
619 Granite Bldg. (Pres., 1901).....St. Louis, Mo.
Kirk, Geo. H., 6612 Wentworth Ave.....Chicago, Ill.
Kitchen, John H., 901 Broadway.....Kansas City, Mo.
Klemm, J. George, Jr., 420 Arcade Bldg.....Philadelphia, Pa.
Kries, H. A., 227 West Saratoga St.....Baltimore, Md.

Lamb, Foster W., 259 E. Kinzie St.....Chicago, Ill.
Leek, Walter.....Vancouver, B. C.
Lewis, Samuel R., 1200 Michigan Ave.....Chicago, Ill.
Libby, L. R., 164 State St.....Hartford, Conn.
Lisk, J. P., 239 West 39th St.....New York.
Lowenberg, L., 311 Fourth National Bank Bldg..Cincinnati, O.
Lyman, C. M., 22 Broad St.....Utica, N. Y.

Mackay, James, 1200 Michigan Ave. (Pres., 1908).Chicago, Ill.
Mackay, Wm. M., 113 Beekman St. (Pres., 1897)..New York.
MacNichol, F. F., 217 Main St.....Oshkosh, Wis.
Maguire, Wm. Robt., 10 Dawson St.....Dublin, Ireland.
Mallory, H. C., 100 Broadway.....New York.
Mappett, A. S., 380 Bourse Bldg.....Philadelphia, Pa.
May, Edwin A., 282 Michigan Ave.....Chicago, Ill.
McArthur, Chas. D., 144 Beech St.....Arlington, N. J.
McCann, Frank G., 500 Park Ave.....New York.
McGinness, J. E., 541 Wood St.....Pittsburg, Pa.
McKiever, Wm. H., 292 Avenue B.....New York.

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McPherson, W. G., 328 Glisan St.....Portland, Ore.
Mechling, F. M., 203 German Bank Bldg.....Pittsburg, Pa.
Mehring, Geo., 24 Sherman St.....Chicago, Ill.
Merritt, Jas. H., 48 Cliff St.....New York.
Meyer, Henry C., Jr., 1 Madison Ave.....New York.
Mobley, Edw. S., 100 W. Patrick St.....Frederick, Md.
Moffett, Wm. S., R. F. D. No. 3.....Staunton, Va.
Morgan, D. F., 676 Granville Ave.....Chicago, Ill.
Morrin, Thos., 15 Second St.....San Francisco, Cal.
Morrison, Hugh S., P. O. Box 652.....Richmond, Va.
Mott, A. C., Amer. & Dauphin Sts.....Philadelphia, Pa.
Muellenbach, H. W. E., Schanzenstrasse 75. Hamburg, Germany.
Mulford, C. C., 215 Park Place.....Brooklyn, N. Y.
Munroe, Edwards K., 106 S. Gay St.....Baltimore, Md.
Murphy, Everett N., 112 E. Lake St.....Chicago, Ill.

Neal, Ambrose O., 161 East 84th St.....New York.
Neiler, Samuel G., 1409 Manhattan Bldg.....Chicago, Ill.
Nesbit, D. M., 12 Great Jones St., Bedford Row..London, Eng.
Newport, Chas. F., 6312 Wentworth Ave.....Chicago, Ill.

O'Hanlon, George, 320 East 30th St.....New York.
Oldacre, C. E., 160 Baldwin St.....Toronto, Ontario, Canada.
Osbourn, M. P., Point & Elm Sts.....Camden, N. J.

Patterson, N. L., 710 Tribune Bldg.....Chicago, Ill.
Patterson, W. S.....Appleton, Wis.
Paul, Andrew G., 622 Warren St.....Boston, Mass.
Payne, John A., 33 Clendenny Ave.....Jersey City, N. J.
Perkins, Frederick R., 523 Wilson Bldg.....Dallas, Texas.
Pittelkow, A. G., 415 South 15th St.....Omaha, Neb.
Pope, Wm. A., 80 Lake St.....Chicago, Ill.
Prizer, Chas. S., Amer. & Dauphin Sts.....Philadelphia, Pa.

Quay, D. M., 716 Townsend Bldg. (Pres., 1900)...New York.

Reck, Anders B., The Reck Heating Co., Ltd.,
Esromgade.....Copenhagen, Denmark.
Reed, Alvin D., Pierce Bldg.....St. Louis, Mo.
Rice, Daniel J., 103 Park Ave.....New York.
Riley, Champlain L., 7 Myrtle Ave.....N. Plainfield, N. J.

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Ritter, H. H., 1 Liberty St.....New York.
Robbins, Loring G., 68 West St.....Pittsfield, Mass.
Robertson, Geo. A., 438 Lafayette Ave.....Brooklyn, N. Y.
Robinson, Harry A., 1409 Manhattan Bldg.....Chicago, Ill.
Rouquaud, Lucien, 88 Ave. Victor Hugo.....Paris, France.
Russell, Joseph N., 22 Charing Cross..London, S. W., England.
Rutzler, Enoch, 127 White St.....New York.
Ryan, Edw. J.....Danville, Ill.

Sabin, Frederick, 237 North Bread St.....Philadelphia, Pa.
Sadler, John T., 122 Lake St.....Elmira, N. Y.
Schaffer, John P., 209 Wood St.....Pittsburg, Pa.
Schlemmer, Oliver, 1050 Hulbert Ave.....Cincinnati, O.
Schlemmer, Oliver H., 1050 Hulbert Ave.....Cincinnati, O.
Scollay, U. G., 76 Myrtle Ave.....Brooklyn, N. Y.
Scott, Chas. E., 1123 Broadway.....New York.
Scott, Geo. Welsby, 1301 Security Bldg.....Chicago, Ill.
Scott, Robt., 1716 Ludlow St.....Philadelphia, Pa.
Sekido, Kunisuke, care Takata & Co.....Tokio, Japan.
Seward, P. H., 76 Centre St.....New York.
Shanklin, John R.....Charleston, W. Va.
Sherman, L. B., 15 Murray St.....New York.
Simpson, Geo. T., 408 Pioneer Press Bldg.....St. Paul, Minn.
Slotboom, C. M., Wagenstraat 96.....The Hague, Holland.
Smith, H. A., Hartland.....Niagara Co., N. Y.
Snow, Wm. G., 1108 Penn Mutual Bldg.....Boston, Mass.
Snyder, C. B. J., 500 Park Ave. (Pres., 1907).....New York.
Sparrow, Ernest P., care B. F. Sturtevant Co..Hyde Park, Mass.
Spear, John J., 65 W. Lake St.....Chicago, Ill.
Stangland, B. F., 45 Fulton St.....New York.
Stannard, Jas. M., 231 E. Randolph St.....Chicago, Ill.
Stibbs, Geo. H., 176 Bridge St.....Springfield, Mass.
Still, Fred R., 1400 Russell St.....Detroit, Mich.
Stock, Edw. L., 1013 9th St., N. W.....Washington, D. C.
Stockwell, W. R.....Irvington-on-Hudson, N. Y.
Switzer, Wm. H., 115 Genesee St.....Utica, N. Y.
Symms, Chas. D.....Sioux Falls, S. Dak.

Tait, James J., 2146 Golden Gate Ave.....San Francisco, Cal.
Tait, Thomas, 631 J St.....Sacramento, Cal.
Talcott, R. B., 427 Fifth Ave.....New York.

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Theorell, H. G. T.....Stockholm, Sweden.
Thompson, Nelson S., care Jos. McWilliams & Co.....Louisville, Ky.
Thompson, R. S.....Springfield, O.
Thomson, T. N., 1033 Ridge Row.....Scranton, Pa.
Tobin, Geo. J., 187 North Ave.....Plainfield, N. J.
Traschel, J. C. F., 230 Arch St.....Philadelphia, Pa.
Trainor, John, 877 N. Howard St.....Baltimore, Md.

Van Buren, H. B., 133 Cherry St.....Battle Creek, Mich.
Varney, Alvin W., 359 Campbell Ave.....Detroit, Mich.
Vrooman, Wm. C., 138 State St.....Schenectady, N. Y.

Waggoner, E. P., 59 13th St.....Hoboken, N. J.
Walker, J. J., L. Box 22.....Sheridanville, Pa.
Warsop, Chas. E., 825 State Life Bldg.....Indianapolis, Ind.
Washburn, Wm. S., 1363 Main St.....Campello, Mass.
Waters, T. J., 710 Tribune Bldg.....Chicago, Ill.
Webster, Warren, Point & Elm Sts.....Camden, N. J.
Weinshank, Theo., 729 Newton Claypool Bldg.....Indianapolis, Ind.
Welsh, Harry S., 67 Exchange St.....Rochester, N. Y.
Wentz, Geo. H., P. O. Box 659.....Lincoln, Neb.
Weymouth, Geo. H., 8 Dover St.....New York.
Wheeler, Louis H.....Hancock, N. Y.
Widdicombe, Robt. A., 2573 Lakewood Ave., Edgewater Sta.....Chicago, Ill.
Wiley, Edgar C.....Lynchburg, Va.
Willard, Harvey R., 188 Madison St.....Chicago, Ill.
Williams, Francis A., 211 West 20th St.....New York.
Wilson, H. A., 236 Congress St.....Boston, Mass.
Wilson, J. J., 3000 Euclid Ave.....Philadelphia, Pa.
Wing, L. J., 90 West St.....New York.
Wolf, Wm. C., 311 N. 2d St.....Elkhart, Ind.
Wolfe, Wiltsie F., 668 Bourse Bldg. (Pres., 1898).....Philadelphia, Pa.

Yates, Walter, Parksend, Swinton.....Manchester, England.

Zeck, Alex.....Grafton, W. Va.

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## ASSOCIATE MEMBERS.

Allen, John K., 49 N. Jefferson St.....Chicago, Ill.
Armagnac, A. S., 1123 Broadway.....New York.
Birdsall, Wm. A., 675 Hunterdon St.....Newark, N. J.
Boylston, John, 112 E. Lake St.....Chicago, Ill.
Corbett, Frank J., 128 Liberty.....New York.
Curtis, Joseph W.....Norwich, Conn.
Gombers, Henry B., 260 West Broadway.....New York.
Graham, Joseph, 239 West 39th St.....New York.
Green, E. N., Willow & Wood Sts.....Houston, Texas.
Greenman, Geo. L., 46 East 20th St.....New York.
Heatherton, Jas. M., 45 West 34th St.....New York.
Hess, Harry H., 129 Worth St.....New York.
Jennings, Fred'k W., care Ashwell & Nesbit,
Ltd.....Leicester, Eng.
Kellogg, C. V., 1200 Michigan Ave.....Chicago, Ill.
Larsen, Lewis A., 3931 W. 6th St.....Duluth, Minn.
Martin, Harry S., U. S. Radiator Co.....Dunkirk, N. Y.
Martin, Jas. H., Jr., 180 East 41st St.....Chicago, Ill.
McCrum, Lloyd G., 46 East 20th St.....New York.
Monash, Mark E., 90 Centre St.....New York.
Robinson, S. Whitmore, 12 Great James St.,
Bedford Row.....London, Eng.
Rossman, V. D., 313 Chestnut St.....St. Louis, Mo.
Scudder, Wm. M., 40 Dearborn St.....Chicago, Ill.
Smith, Chas. A., 722 Dwight Bldg.....Kansas City, Mo.

## JUNIOR MEMBERS.

Dornheim, G. A., 464 West 146th St.....New York.
Fox, W. Scott, 233 Edgewood Ave.....Dayton, O.
Hill, Norman A., 1503 Sansom St.....Philadelphia, Pa.
Hogan, Daniel, 701 Mo. Trust Bldg.....St. Louis, Mo.
Knickerbocker, J. P., Amer. Dist. Steam Co....Lockport, N. Y.
Lynd, Roy E.....Dover, N. J.
Natkin, Benj., 425 Shukert Bldg.....Kansas City, Mo.
Nichols, Geo. W., 212 So. 7th St.....Philadelphia, Pa.
Ott, Harry J., 1210 Manhattan Bldg.....Chicago, Ill.

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Parter, Samuel C., 1991 Washington Ave.....New York.
Phillips, Lee, 115 Beaver Road.....Emsworth, Pa.
Schlemmer, Edmund, 1050 Hulbert Ave.....Cincinnati, O.
Soleau, Edward W., 21 Camfield St.....Newark, N. J.
Tjersland, Alf., care E. Sunde & Co.....Christiania, Norway.
Ulrich, John E., 1308 24th St.....Louisville, Ky.
Woodling, Miner D., 926 S. Main St.....Independence, Mo.

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| James W. Gifford, Attleboro, Mass. | Jan. 1898, | July 26, 1899. |
| William McMannis, New York | Sept. 1894, | Jan. 19, 1901. |
| Charles F. Tay, San Francisco, Cal. | Jan. 1896, | Sept. 8, 1901. |
| Arthur H. Fowler, Philadelphia, Pa. | Jan. 1897, | June 3, 1903. |
| Stephen G. Clark, New York | Dec. 1902, | Feb. 3, 1904. |
| Charles M. Wilkes, Chicago, Ill. | Jan. 1897, | Jan. 7, 1905. |
| James Curran, New York | Dec. 1901, | Oct. 27, 1905. |
| Herbert W. Nowell, New York | June 1904, | Mar. 25, 1906. |

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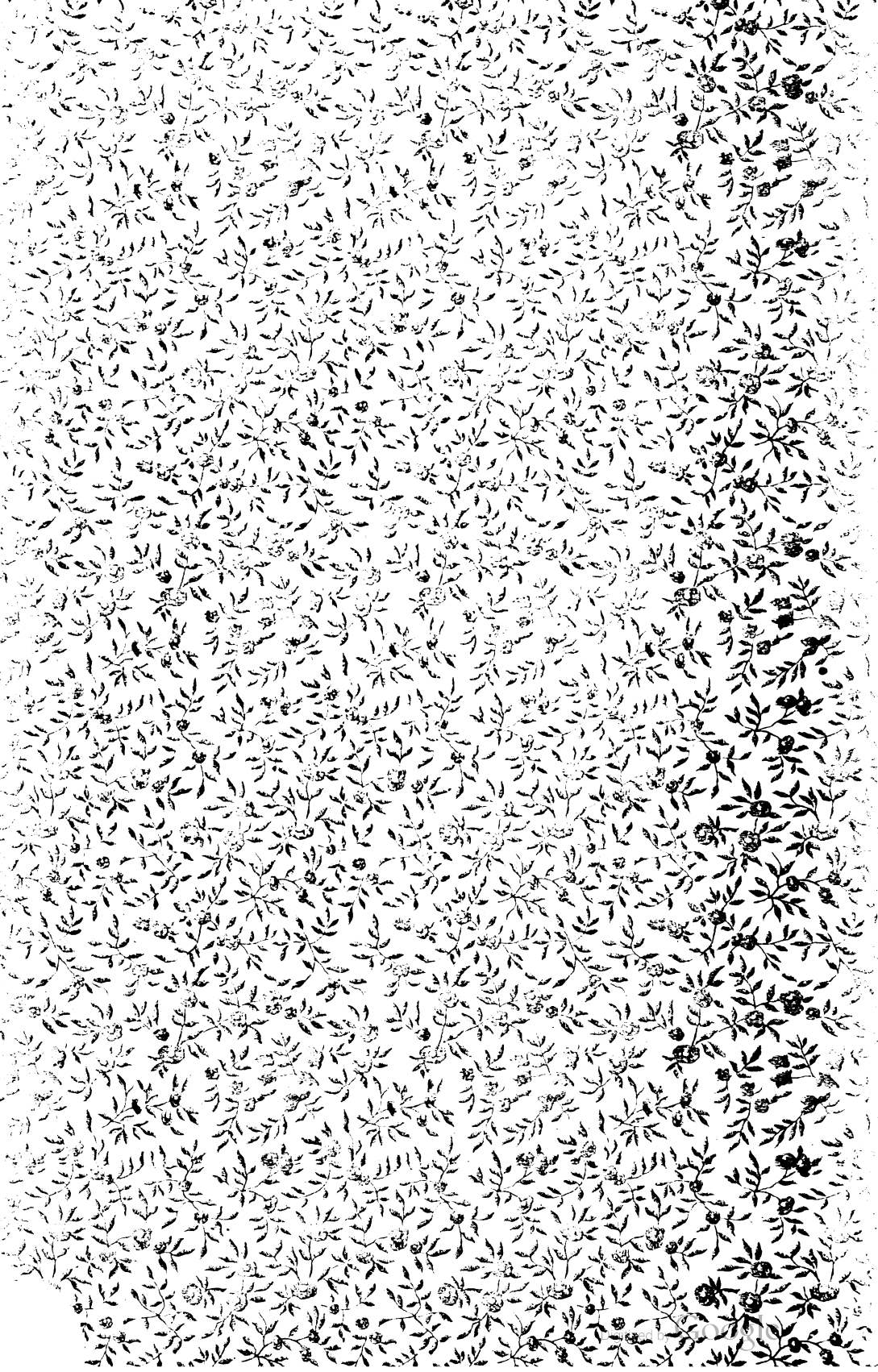
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